This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,067,207

QE
1
J86

THE

JOURNAL OF GEOLOGY

A Semi-Quarterly Magazine of Geology and
Related Sciences

112763

EDITORS

T. C. CHAMBERLIN, *in General Charge*

R. D. SALISBURY
Geographic Geology
J. P. IDDINGS
Petrology
STUART WELLER
Paleontologic Geology

R. A. F. PENROSE, JR.
Economic Geology
C. R. VAN HISE
Pre-Cambrian Geology
W. H. HOLMES
Anthropic Geology

ASSOCIATE EDITORS

SIR ARCHIBALD GEIKIE
Great Britain
H. ROSENBUSCH
Germany
CHARLES BARROIS
France
ALBRECHT PENCK
Austria
HANS REUSCH
Norway
GERARD DE GEER
Sweden
GEORGE M. DAWSON
Canada

O. A. DERBY
Brazil
G. K. GILBERT
Washington, D. C.
H. S. WILLIAMS
Yale University
JOSEPH LE CONTE
University of California
C. D. WALCOTT
U. S. Geological Survey
J. C. BRANNER
Stanford University
I. C. RUSSELL
University of Michigan

WILLIAM B. CLARK, *Johns Hopkins University*

VOLUME IX

CHICAGO
The University of Chicago Press
1901

PRINTED BY
The University of Chicago Press
CHICAGO

CONTENTS OF VOLUME IX.

NUMBER I.

PAGE
PROBLEM OF THE MONTICULIPOROIDEA. Frederick W. Saerdson - - 1
THE EXCURSION TO THE PYRENEES IN CONNECTION WITH THE EIGHTH INTERNATIONAL GEOLOGICAL CONGRESS Frank Dawson Adams - 28
VALLEYS OF SOLUTION IN NORTHERN ARKANSAS. A. H. Purdue - - 47
STUDIES FOR STUDENTS: The Structure of Meteorites. I. O. C. Farrington 51
EDITORIAL - - - - - - - - - - - - - - - - - 67
REVIEWS: Summaries of Current North American Pre-Cambrian Literature, by W. C. Leith, 79; The Norwegian Polar Expedition, 1893 to 1896; Scientific Results: edited by Fridtjof Nansen, Vol. I (R. D. S.), 87; The Pleistocene Geology of the South Central Sierra Nevada, with especially Reference to the Origin of the Yosemite Valley, by Henry Ward Turner (R. D. S.), 90; A Record of the Geology of Texas for the Decade ending December 31, 1896, by Frederic W. Simonds (J. C. Branner), 91.
RECENT PUBLICATIONS - - - - - - - - - - - - - - 92

NUMBER II.

ON THE ORIGIN OF THE PHENOCRYSTS IN THE PORPHYRITIC GRANITES OF GEORGIA. Thomas L. Watson - - - - - - - - - 97
CERTAIN PECULIAR ESKERS AND ESKER LAKES OF NORTHEASTERN INDIANA. Charles R. Dryer - - - - - - - - - - - 123
CORRELATION OF THE KINDERHOOK FORMATIONS OF SOUTHWESTERN MISSOURI. Stuart Weller - - - - - - - - - - - - - 130
PROBLEM OF THE MONTICULIPOROIDEA. II. F. W. Sardeson. - - - - 149
STUDIES FOR STUDENTS: The Structure of Meteorites. II. O. C. Farrington 174
EDITORIAL - - - - - - - - - - - - - - - - - 191
REVIEWS: Zeiller's Flora of the Carboniferous Basin of Heraclea: An Illustration of Paleozoic Plant Distribution (David White), 192; Géologie et minéralogie appliquées; Les mineraux utiles et leurs gisements, par Henri Charpentier (J. C. Branner), 198; Handbuch der Seenkunde; Allgemeine Limnologie, by F. A. Forel (R. D. S.), 199; A Preliminary Report on the Artesian Basins of Wyoming, by Wilbur C. Knight (R. D. S.), 200. Die vierte Eiszeit im Bereiche der Alpen, von Albrecht Penck (R. D. S.), 202.
RECENT PUBLICATIONS - - - - - - - - - - - - - - 203

NUMBER III.

PAGE
THE CLASSIFICATION OF THE WAVERLY SERIES OF CENTRAL OHIO. Charles S. Prosser - 205
THE USE OF BEDFORD AS A FORMATIONAL NAME. Edgar R. Cumings - 232
ON THE USE OF THE TERM "BEDFORD LIMESTONE." C. E. Siebenthal - 234
NITRATES IN CAVE EARTHS. Henry W. Nichols - 236
DERIVATION OF THE TERRESTRIAL SPHEROID FROM THE RHOMBIC DODECAHEDRON. Charles R. Keyes - 244
THE VARIATIONS OF GLACIERS. VI. Harry Fielding Reid. - 250
PRODROMITES, A NEW AMMONITE GENUS FROM THE LOWER CARBONIFEROUS. James Perrin Smith and Stuart Weller - 255
EDITORIAL - 267
REVIEWS: The Norwegian North Polar Expedition, 1893–1896: Scientific Results, Vol. II, edited by Fridtjof Nansen (T. C. C.), 273; Meteorological Observations of the Second Wellman Expedition, by Evelyn B. Baldwin, Observer, Weather Bureau; Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900, Part VII (T. C. C.), 276; The Oriskany Fauna of the Becraft Mountain, Columbia County, N. Y., by J. M. Clark (S. W.), 278.
RECENT PUBLICATIONS - 280

NUMBER IV.

GLACIAL AND INTERGLACIAL BEDS NEAR TORONTO. A. P. Coleman - 285
PORTABLE REPRESENTATIVES OF PRE-WISCONSIN TILL IN SOUTHEASTERN MASSACHUSETTS. Myron L. Fuller - 311
SKETCH OF THE GEOLOGY OF THE SALINAS VALLEY, CALIFORNIA. Edward Hoit Nutter - 330
NOTES ON THE FOSSILS FROM THE KANSAS-OKLAHOMA RED-BEDS. Charles Newton Gould - 337
ILLUSTRATED NOTE ON A MINIATURE OVERTHRUST FAULT AND ANTICLINE. A. H. Purdue - 341
THE MORRISON FORMATION OF SOUTHEASTERN COLORADO. Willis T. Lee - 343
EDITORIAL - 353
REVIEWS: Department of Geology and Natural Resources of Indiana, Twenty-fifth Annual Report, by W. S. Blatchley, State Geologist (C. E. Siebenthal), 354; Summary Report of the Geological Survey Department [of Canada] for the year 1900 (C.), 357; Aus den Hochregionen des Kaukassus, by Gottfried Merzbacher (J. P. I.), 359; The Geological History of the Rivers of East Yorkshire, by F. R. Cowper Reed (T. C. C.), 360; The Conveyance of Water in Irrigation Canals, Flumes, and Pipes,

PAGE

by Samuel Fortier (G. B. H.), 361; The University Geological Survey of Kansas, Vol. IV., Paleontology, Part II, by Samuel W. Williston (S. W.), 362; Profiles of Rivers in the United States, by Henry Gannett (G. B. H.), 363; Yearbook of the United States Department of Agriculture for 1900 (C.), 363.

RECENT PUBLICATIONS - - - 364

NUMBER V.

ON A POSSIBLE FUNCTION OF DISRUPTIVE APPROACH IN THE FORMATION OF METEORITES, COMETS, AND NEBULÆ. T. C. Chamberlin - - - 369

STUDIES FOR STUDENTS: THE CONSTITUENTS OF METEORITES, I. O. C FARRINGTON - - - 393

THE PALEOZOIC FORMATIONS OF ALLEGANY COUNTY, MARYLAND. Charles S. Prosser - - - 409

THE DEPOSITION OF COPPER BY SOLUTIONS OF FERROUS SALTS. H. C. Biddle - - - 430

EVIDENCE OF A LOCAL SUBSIDENCE IN THE INTERIOR. John T. Campbell - 437

EDITORIAL - - - 439

REVIEWS: Summaries of Current North American Pre-Cambrian Literature (C. K. Leith), 441; On Rival Theories of Cosmogony, by O. Fisher (T. C. C.), 458; Glacial Sculpture of the Bighorn Mountains, Wyoming, by François E. Matthes (R. D. S.), 465; Annual Report of the Board of Regents of the Smithsonian Institution (C.), 466.

RECENT PUBLICATIONS - - - 467

NUMBER VI.

THE RIVER SYSTEM OF CONNECTICUT. William Herbert Hobbs - - - 469

COMPOSITE GENESIS OF THE ARKANSAS VALLEY THROUGH THE OZARK HIGHLANDS. Charles R. Keyes - - - 486

A SECOND CONTRIBUTION TO THE NATURAL HISTORY OF MARL. Charles A. Davis - - - 491

PERKNITE (LIME-MAGNESIA ROCKS). H. W. Turner - - - 507

THE BORDER-LINE BETWEEN PALEOZOIC AND MESOZOIC IN WESTERN AMERICA. James Perrin Smith - - - 512

STUDIES FOR STUDENTS: THE CONSTITUENTS OF METEORITES, II. Oliver C. Farrington - - - 522

MEMORIAL - - - 533

EDITORIAL - - - 535

PAGE

REVIEWS: Three Phases of Modern Paleontology; (I) Uintacrinus: Its Structure and Relations, by Frank Springer; (II) Oriskany Fauna of Becraft Mountains, by John M. Clark; (III) Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field, by David White (Charles R. Keyes), 539; Iowa Geological Survey, by Samuel Calvin, State Geologist; A. G. Leonard, Assistant State Geologist; Annual Report for 1900 (H. F. B.), 547; Beach Structures in the Medina Sandstone, by H. L. Fairchild (N. M. F.), 549; The Beaufort's Dyke, off the Coast of the Mull of Galloway, by H. G. Kinahan (N. M. F.), 551.

RECENT PUBLICATIONS - - - - - - - - - - - - - - 552

NUMBER VII.

INDIVIDUALS OF STRATIGRAPHIC CLASSIFICATION. Bailey Willis - - - 557

THE DISCRIMINATION OF TIME-VALUES IN GEOLOGY. Henry Shaler Williams 570

VARIATIONS OF TEXTURE IN CERTAIN TERTIARY IGNEOUS ROCKS OF THE GREAT BASIN. J. E. Spurr - - - - - - - - - - 586

THE FOYAITE-IJOLITE SERIES OF MAGNET COVE: A CHEMICAL STUDY IN DIFFERENTIATION. Henry S. Washington - - - - - - 607

THE PRE-TERRESTRIAL HISTORY OF METEORITES. Oliver C. Farrington - 623

EDITORIAL - - - - - - - - - - - - - - - - 633

REVIEWS: Zinc and Lead Region of North Arkansas, by John C. Branner (C. R. Keyes), 634; Texas Petroleum, by William Battle Phillips (C. E. S.), 637; Lessons in Physical Geography, by Charles R. Dryer (N. M. F.), 638; Some Notes Regarding Vaerdal: The Great Landslip, by Dr. Hans Reusch (N. M. F.), 639; Geological Map of West Virginia, by I. C. White, 640.

RECENT PUBLICATIONS - - - - - - - - - - - - - 642

NUMBER VIII.

THE FOYAITE-IJOLITE SERIES OF MAGNET COVE: A CHEMICAL STUDY IN DIFFERENTIATION, II. Henry S. Washington - - - - - - 645

PECULIAR EFFECTS DUE TO A LIGHTNING DISCHARGE ON LAKE CHAMPLAIN IN AUGUST, 1900. William Hallock - - - - - - - - - 671

STUDY OF THE STRUCTURE OF FULGURITES. Alexis A. Julien - - - - 673

PHYSIOGRAPHY OF THE BOSTON MOUNTAINS, ARKANSAS. A. H. Purdue - 694

THE DISCOVERY OF A NEW FOSSIL TAPIR IN OREGON. William J. Sinclair - 702

THE FORMATION AS THE BASIS FOR GEOLOGIC MAPPING. Edwin C. Eckel - 708

PAGE
GLACIAL WORK IN THE WESTERN MOUNTAINS IN 1901. Rollin D. Salisbury 718
REVIEWS: Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, by N. H. Darton (George D. Hubbard), 732; The High Plains and Their Utilization, by Willard D. Johnson (George D. Hubbard), 734; The Bauxite Deposits of Arkansas, by Charles Willard Hayes (Thomas L. Watson), 737.
RECENT PUBLICATIONS - - - - - - - - - - - - - - 740
INDEX TO VOLUME IX - - - - - - - - - - - - - - 743

THE

JOURNAL OF GEOLOGY

JANUARY–FEBRUARY, 1901

PROBLEM OF THE MONTICULIPOROIDEA. I.

THE Monticuliporoidea, comprising the greater part of the so-called Paleozoic Bryozoa, are a comparatively neglected group of fossils, as evidenced in such ways as frequent omission or slight mention of them in lists of fossils or descriptions of faunas. They are not, however, really without great scientific value, but rather their unpopularity may be due to the fact that at present there is a real difficulty for the amateur, the collector, or the geologist in making use of them; this difficulty being magnified, moreover, by a too readily accepted supposition that these fossils are for none but gifted specialists to study. In fact, the specimens themselves are very often excellent, the species quite easy to learn or to identify, and well worthy of consideration as to scientific value in geologic faunas, and the entire group is of peculiar interest to biology.

Aside from the retarding supposition that the Monticuliporoidea are difficult, the present difficulties attending them are these: (1) the interpretation of the animal that built the honeycomb-structured organic remains is still uncertain; (2) the monographs in which they are described want censorship; (3) study of the fossil involves technique more or less. These obstructions are, however, not absolute. It is the aim of this discussion to render them better understood, and hence less feared.

Regarding their interpretation, uncertainty exists to the extent that all Monticuliporoidea may be contested as not true Bryozoa, but Tabulata or Alcyonarian corals, belonging then to a different subkingdom of animals. This uncertainty may be illustrated as to its attendant difficulties by reference to Eastman's[1] *Text-book of Paleontology*, Vol. I, where *Prasopora, Neuropora*, and many other genera appear twice, first under Cœlenterata and second under Bryozoa; the first following the text of Zittel, the second the authority of the translator's collaborator, who has taken the liberty to make some revision.

The fact that one cannot assert positively that species of the genus *Prasopora* and other genera were Cœlenterates or were Bryozoons, is due to outward similarity of these two groups and obscurity in the fossils as to class characters. Yet structural details as to minor characters are well preserved, and hence the distinction of species and their grouping into genera is not impracticable here more than in many other groups, since species may be distinguished clearly in fossils as in living organisms without knowledge of phylogenic relation to other classes. Ulrich, who considers them all as Bryozoa, and Nicholson, who treated them as corals, ought nevertheless to present the same determinations as to species, genera, and families. Their failure to agree is not due to that cause. However, the former, in Eastman's translation of Zittel (*op. cit.*), presents as families of Bryozoa (viz., Calloporidæ, etc.) those which, following Nicholson (*vide op. cit.*, pp. 103–105), are given as genera Callopora, etc., of Cœlenterata. Understanding this discrepancy, the handbook is as useful respecting these as other groups, and the fossils are as easily used under its guidance. The student may choose his authority or follow a happy median course.

The lack of censorship in Eastman's *Paleontology*, just mentioned, may serve to argue further need of it in other places. S. A. Miller's catalogue[2] divides the Monticuliporoidea species between Cœlenterata and Bryozoa. Of other chief works, especially those of Nicholson,[1] we may trust E. O. Ulrich to have criticised them fully. They are conservative and excellent, but inadequate for the study of American fossils without the magnificent recent monographs by E. O. Ulrich[2] to supplement them. The last named, together with the chapter on Bryozoa in Eastman's *Paleontology*, would have offered a complete solution to the student for the study of the fossils and the involved problem of their affinities, if it were not for much obscurity in his definitions. One is compelled to criticise and to interpret anew from the fossils when endeavoring to follow him. In this connection it should be said also that the severe criticism of E. O. Ulrich, by S. A. Miller, *op. cit.*, while touching his works on Paleozoic Bryozoa, does not appear to reach by censorship of the species this group as much or as well as other ones, for the reason, evidently, that his knowledge of them did not permit him. Therefore, while all species are listed as equally valid, some will be found, nevertheless, to have been made upon wholly insufficient evidence and require to be freely eliminated. The most species will again be far easier to identify than their descriptions would lead one to expect. It appears, in short, necessary to admit the value of some earlier criticism[3] of this author, and to expect to find similarities and differences described with acuteness, while fanciful values are frequently attached to them.

---

[1] Text-book of Paleontology, by KARL A. VON ZITTEL, translated by Charles R. Eastman, 1900.

[2] S. A. MILLER, North American Geology and Paleontology.

Regarding the handling of fossil Monticuliporoidea, one should collect all specimens and in the laboratory select the better preserved ones to begin with. These may be assorted and identified by means of external characters. A common hand lens will suffice to reveal whatever may be not clear to the naked eye. To be sure, the exhaustive study of the material requires the making and use of thin sections when practicable, for often only by that means can the also important internal structure be discovered. The use of thin sections is, however, necessarily limited to special cases. These would be when a new species is in hand and all characters possible should be discovered; or, when a described species is illustrated and described chiefly as to its internal structure, which too frequently is the case; or, when the external characters have been obliterated. Having identified the species and referred it to a genus, etc., by use of all characters, further recognition of specimens of the same can and should, with rare exception, be made to depend on external characters alone. As in studying Brachiopoda, for example, one must know them by external characters, even though examination of internal structures is required to determine affinities of the species.

---

[1] H. A. NICHOLSON, On the Structure and Affinities of the Genus Monticulipora 1881.

[2] Geol. Surv. Ill., Rept., Vol. VIII, and Geol. Surv., Minn., Final Rept., Vol. III.

[3] ROMINGER, Amer. Geol., Vol. VI, pp. 103 and 120, 1890.

The advantage of learning to recognize the species, genera, etc., by external characters is in the saving of time, since thousands can be examined in that way, while sectioning limits the labor of one man to at most twenty specimens per day; knowledge of the range and variability of one and many species is made practicable; it serves to direct to best advantage the use of thin sectioning; recognition of species even in the field becomes thereby entirely practicable. Having learned to know a group of species, or the fauna of a locality or of a zone, the specimens may be identified thereafter without the use of sectioning, and the difficulty of technique may be obviated by the geologist.

Thin sections of fossils may be made by the same process as bone or rock sections are ground, which need not be described here. It requires less skill, however, since they should not be ground to absolute thinness. Some simple appliance for measuring the cell dimensions is also needed.

Pains may be saved by attention in collecting, since each bed or zone may have a large proportion of species peculiar to it, and by avoiding mixing fossils of different zones, labor of again assorting is saved.

TREPOSTOMATA

A few selected species may illustrate what is to be looked for in Monticuliporoidea. Beginning with Trepostomata one then has to do with the most problematic as to affinities of the so-called Paleozoic Bryozoa, *i. e.*, those which most resemble corals, proceeding then to those often supposed to be true Bryozoa, the Cryptostomata. Eastman's manual, *op. cit.*, includes them in the arrangement given below, and in the Order Gymnolæmata, which comprises most Bryozoa and all known fossil ones. Of those five divisions, the last named, Chilostomata, are all undoubtedly Bryozoa, but are not known in the Paleozoic rocks. The first, Cyclostomata, are, with few possible exceptions, all true Bryozoa, but few of them are Paleozoic. The second, third, and fourth comprise the Monticuliporoidea.

1. Cyclostomata (8 families).
2. Families doubtfully referred to Cyclostomata (4 families).
3. Trepostomata (7 families).
4. Cryptostomata (8 families).
5. Chilostomata (13 families).

In that arrangement those of doubtful affinities are embraced between the true Bryozoa. A fairer presentation of the problem may be given thus:

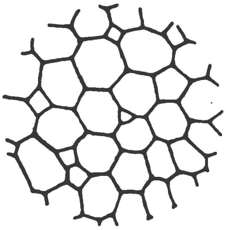
Tabulata (corals)——Trepostomata (?)——Cyclostomata (bryozoa)
Cryptostomata (?)   Chilostomata (bryozoa)

and it is in such association that the Monticuliporoidea should be studied. The group of "Doubtfully referred to Cyclostomata" are Trepostomata.

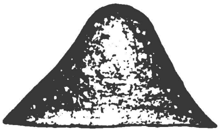
Beginning with one of the simpler Trepostomata,

Monotrypa magna Ulr. has a skeleton or zoarium one or two inches in diameter, composed of tubes or "cells" which radiate from an approximate center. It is nearly spherical if growing attached on one point, or discoid if on a flat surface, or, again, irregular. The center is the initial or oldest part, and from it one, or practically several, cells arise, and as these extend, others intercalate successively. A specimen divided radially (Pl. A, Fig. 2) shows parallel, approximately equal, cells, each tapering to a point at the inner end. The plan of growth is that of increase in number of cells proportionate to the increase in size of the zoarium. At the surface, the open cell ends are

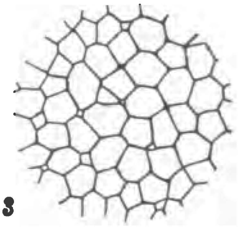
JOUR. GEOL., Vol. IX, No. 1 Plate A



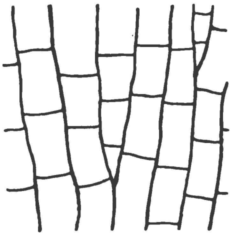
1



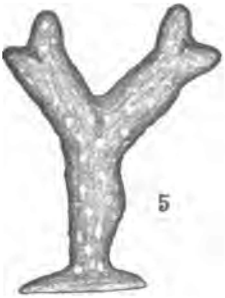
7



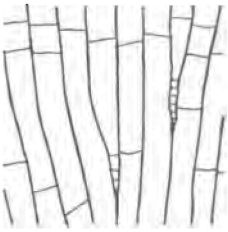
3



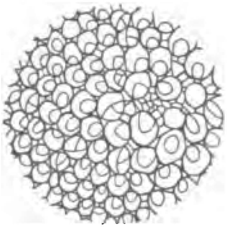
2



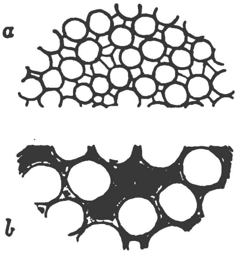
5



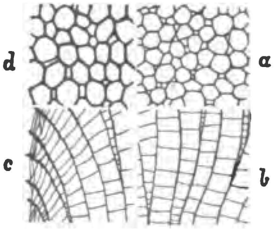
4



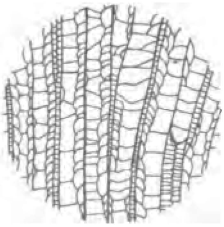
8



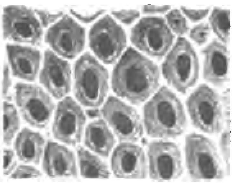
10



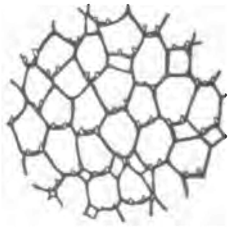
6



9



11



12

approximately equal, and, like the cell throughout, are polygonal or hexagonal by reason of contact (Pl. A, Fig. 1). The incipient or expanding parts of cells are seen there as small tri-, or quadrangular openings at the angles between the older, larger cells. Crowding of the cells appears to prevent entire regularity in shape and size of each cell, and the walls are crenulate.

In speaking of cell one includes for each the half of the bounding wall, although the walls originally are dense, amalgamated, calcareous structures, not double further than that they were built not only by increment upon their margins, but also on the two surfaces. Theoretically there is a boundary plane or division between cells midway in the wall. They frequently split midway in the wall when fractured. The walls in this species are thin and show little or none of their growth structure. At a slight depth within each cell the last growth increment or layer crosses the cell opening and forms a transverse partition or false bottom, the so-called tabula. Tabulæ occur successively in all cells more or less regularly, but not corresponding in neighboring cells. They are a little more numerous in the incipient part of each cell. The wall edge of one cell cannot extend above those of its neighbors, from which it never separates.

The zoarium corresponds in structure to the following supposed manner of growth: It was covered when alive by numerous equal sized zooids which coalesced laterally, the lower part of each, however, extending into and secreting the walls forming the cell or zoœcium. Young zooids arose among them and, growing, extended relatively downward, building a new cell; the increase in number of zooids and, respectively, cells, being compensated by a necessary growth in radial length of cell wall to increase the surface of the inhabited zoarium. The tabulæ indicate successive planes where the bottom of the zooid rested between periods of necessitated self-extraction from the ever too long cell.

E. O. Ulrich assumes that the cells are "Zoœcia, directly superimposed upon one another so as to form long tubes intersected by straight or curved partitions . . . ." That interpretation appears in form of a definition only; and not knowing how it could be applied to the initial part of cells, respectively young zooids, which then must be supposed to have required several generations to reach maturity, the other interpretation will be kept for the present, viz., that each cell is one zoœcium.

Variation in such species as this one would consist in the zoarium growing in one part more than another for some cause, being one-sided; or it is discoid because of perigene growth, *i. e.*, the cell increase is greatest around the margin; or, again, it is acrogene. The surface upon which it grew affected its growth also. The cells remain nearly uniformly large, the number of young cells seen at the surface varying. The cell walls appear uniformly thin.

Those characters are seen at the surface or in transverse thin section. Longitudinal section would show the tabulæ to vary, being fewest where cell length most rapidly increased, and the slightly differing rates of expansion of the cell initial. The latter character can also be estimated at the surface. Other species near to this one are in various ways more complex. Thus;

Diplotrypa limitaris Ulr. has nearly the same manner of growth as *Monotrypa magna*, differing in smaller size of cells and shapes of their apertures at the surface (Pl. A, Fig. 3). Here the number of immature cells nearly equals that of the mature ones. Longitudinal section shows that the young or initial part of each cell is long, slowly expanding, or even for some length not increasing, then quite quickly becoming full-sized, mature (see Fig. 4). The tabulæ are closer in these initial parts, technically called *mesopores*. The plan of growth thus differs from that of *Monotrypa magna* in that in the latter new cells appeared only as fast or numerous as they were to develop into mature cells. In *Diplotrypa* the new cells appear too rapidly, so to speak, and await their turn to expand into full size; hence the more numerous small cells, mesopores, among the full-sized autocells at the surface. The calycal or open part of the cell is shallower in small cells or mesopores than in the larger ones, and that is true in all Monticuliporoidea. Also the autocells crowd the mesopores so that the former tend to become circular at the expense of the latter.

Callopora multitabulata Ulr. began like a *Mesotrypa*, but acrogene growth obtained (Pl. A, Fig. 5), the zoarium being long, cylindrical, branched, arising from a basal discoid expansion. The tips, or apices, are only then like small *Mesotrypa*. The greatest growth of zoarium and cell increase was at the zoarial ends, and there the cells increase centrally, so that some were being crowded away and turned their apertures to the peripheral surface, *i. e.*, away from the axis of growth (Pl. A, Fig. 6, *c*). The grown zoarium is thus composed of two regions, the axial or "immature" region of vertical cell part (Fig. 6, *b*, *a*), and the peripheral or "mature" of laterally directed cell (Fig. 6, *c*, *d*). In the peripheral region the cells grew slower in length, have thicker walls and more numerous tabulæ, and there are more mesopore cells. The apical parts also become finally slow-growing, thick-walled, with many tabulæ and many mesopores, and it is evident that the zoarium grew rapidly to nearly full size; then a retarded or "mature" growth followed. Renewed rapid zoarial growth and a second retardation stage often occurs, wherefore the terms immature and mature regions are presumptious terms. Peripheral and axial regions are better, since they leave the degree of maturity to be described. Upon the thick-walled peripheral and apical part there occur at nearly regular intervals elevations called monticules. These are occupied by a small group of larger-sized, cells with mesopores or young cells. On the thin-walled or growing apex, and hence in the axial region, these are represented by a group of likewise slightly large-sized cells, with abundant mesopores, resembling less distinct cell groups occurring in *Monotrypa*, etc. Nicholson proved monticules to be points of greater cell increase, and while young cells may appear at any cell angle, their increase is greatest in the monticules or cell groups. In renewed rapid growth the peripheral monticules tend to develop into branches of the zoarium, but of course all could not. Thus monticules are similar to zoarial branches, but are not branches normally. Branching of the zoarium is due to double region of acrogene growth only.

The tabulæ of *Callopora multitabulata* are thin, and the last one is near the cell aperture, and is said to be perforated at the center (*vide* Eastman, *op. cit.*, *f*, 456 *d*). They are nearly always solid. Right here is the chief supposed basis for the interpretation of Trepostomata as Bryozoa. According to E. O. Ulrich's definition (p. 271, Eastman), each tabula was the perforated top of one zoœcium and solid bottom of the next. In fact, the thickened walls here show only that the growth increments lengthening the wall continue on either side downward, thickening the wall, and thence as tabulæ across the cell opening. Further is not seen. Perforate last tabulæ may be incomplete ones.

The characters for distinction of the species are, therefore, mostly visible on the exterior; the shape of zoarium and its branches, shape, size, and shallow depth of the cells, characters of the monticules, the number, size, and shape of mesopores, and thickness of the wall. All these characters vary, and the variation of all should be noted in learning the species. Extremes may be associated on parts of the same specimen.

Prasopora simulatrix Ulr. grew upon some solid surface, at first lens-shaped, later conical (Pl. A, Fig 7), hemispherical, or irregular, expressing slight tendency to acrogene growth, united with moderate established perigene. A short finger-shaped or a branched sporadic acrogene growth occurs sometimes, and this usually at the center. If the colony died off in part, the remaining part then developed, overspreading the old. Even a symmetrical zoarium could develop from the irregular fragment of another. The cells radiate from the flat or concave lower side to the convex upper one, the lower side being covered, if well preserved, by a thin "epitheca" or coating produced by no one zooid, but by the cortex uniting all. The growth of the epitheca was, of course, marginal. At this margin, close on the epitheca, there was rapid budding of young cells, some of which became quickly full-sized; others became mesopores. At the periphery the cells open obliquely to the zoarial surface. Above it all apertures are more direct.

The number of mesopores in this species (Pl. A, Fig. 8) is so far greater than that of the autocells that relatively few of them can become autocells. They are fewest proportionally in maturer zoaria, and appear to be homologous with those of *Diplotrypa*, only smaller, longer, and, so to say, more permanently mesopores. The numerous small, angular, or impressed mesopores, with shallow openings or calycals, surround the rounded apertures of the thick-walled autocells, making an easily recognized figure at the surface. At intervals occur clusters of cells larger than the average, with more numerous mesopores between them, and thicker walls. They form low monticules, or on weathered specimens high ones. They are areas of rapid cell increase.

The mesopores have numerous transverse tabulæ (Pl. A, Fig. 9). Those of the autocells are numerically proportional, considering the cells' size, but they curve obliquely across, or oftenest form cystiphrams, *i. e.*, the tabulæ in the most regular instances are narrowly beaker-shaped, and are arranged in the cell as nested equal-sized beakers could be in a tube. The flat bottoms have been called diaphragms or tabulæ, the sides cystiphrams. Often the cystiphram extends only partly around the cell, and partly the same lamina is incorporated with the cell wall. Cystiphrams appear to indicate that the zooid body withdrew simultaneously, or nearly so, from the calycal bottom and side, or sides, near the bottom.

The cell wall margins here were not all straight since, *acanthopores* occur. These are minute wart-like structures or thickenings on the cell wall margins, especially at angles, and were presumably built into corresponding invaginations of the living cortex. They are not cells or pores, but have been supposed to be, hence the name. They are inconspicuous in this species or even wanting, and will be discussed later.

Characters sufficient for the determination are upon the exterior in this as in related species. The peculiar cell pattern can be readily distinguished from structurally very similar ones. The variability in cells, acanthopores, etc., will however be found greater, and there are fewer true species of the genus than recorded. Other species of *Prasopora* have more perigene growth, or, again, acrogene ones are the *Monticulapora*.

Homotrypa minnesotensis Ulr. has long, round, slowly-branching zoarium, with many specific marks as to cells, monticules, etc. Fossil stems are in part or entirely hollow, because the axial region has very thin crenulous walls without tabulæ, hence the sea water could enter and eat away the walls, leaving, if anything, the thicker-walled tabulate peripheral region. The peripheral cell has cystiphrams similar to *Prasopora*.

Batostoma fertile Ulr. consists of large, flattened, or round, somewhat irregularly branching acrogene parts, arising from a large basal expansion of irregular perigene growth. A single basal may support more than one or, again, no acrogene part; but as in *Callopora* a thick walled maturity follows the thin walled, immature stage. Thus the characters of peripheral and axial regions are evident when there is even no acrogene growth. Omitting some details, the peripheral region has thick walls on which are well-developed spines, acanthopores. Mesopores may be very few or, again, very numerous on parts of the same specimen (Pl. A, Fig. 10, *a*, *b*). They are "closed," *i.e.*, their tabulæ built close up to the apertural margin, by which the mesopores, being shallow or confluent, look like closed interspaces merely between the rounded autocells. The cell clusters, which are in place of monticules, have *maculæ*, *i. e.*, clusters of mesopores at their center. The young cells of the axial region expand quickly, and are scarcely tabulated and very unlike mesopores of the peripheral region, and they are not called mesopores. The mesopores of the axial region are not immature cells but permanently retarded ones.

With this species is conveniently compared *B.*(*Hemiphragma*) *ottawaense* Foord, in which the thin-walled axial and thick-walled peripheral regions are sharply defined, as seen in thin section or in fractured specimens. At the stage when peripheral region is just begun one sees characters very like *B. fertile*, but later the walls thicken more, the mesopores are obscured, closed, or filled, while the maculose-looking monticules show strongly diverging cells, indicating slow growth in cell length compared to width. Acanthopores developed. The tabulæ are peculiar, being often thickened and incomplete, hemiphragms, in the peripheral region. The whole wall in the fossil is corneus looking. They show the result of a decrease probably of calcareous constituent.

Eridotrypa mutabilis Ulr. includes rather small, long, branched, acrogene zoarial parts in which, as seen in cross fracture or section, the cells are larger in the axial region than in the peripheral. The cells turn very slowly in the peripheral region, so that the apertures are oblique to the surface and drawn out anteriorly. Then, as the cells become more direct, the walls increase steadily in thickness, and in very "old" specimens distinctly cup-shaped calycals form (Pl. A, Fig. 11). The thickened wall permits analysis into the bounding edge with its projection downwards, as dividing lamina, and the calycal slope and the main wall below it (*cf.* Fig. 1, *h*, *p*. 21).

Anolotichia impolita Ulr. has irregular large acrogene zoaria, with large cells of quadrangular rather than polygonal outline, and with few mesopores, reminding of *Monotrypa magna* (Pl. A, Fig. 12). The axial and peripheral regions are scarcely distinguished. In the latter stage there are, however, *lunaria* developed. The lunarium occurs in the posterior side of a full-sized cell as a narrow, distended part of the cell. The term lunarium has been applied rather to the lunarial wall, which is narrowly arcuate or crescentic. Where the lunarial and common cell walls join, in this species, the angles project inwards, as if produced. Moreover the lunarial wall is a little elevated at the surface, making it appear as a distinct wall, but it is really part of the wall deflected and extended. I have searched in vain for the symmetrical crescent that has been figured as the lunarial structure of this species. It appears really to be somewhat irregular, bearing tooth-like points, the downward projections of which appear lucid in thin sections, and are the "vertical, closely-tabulated tubes" described by the author of the genus and species. These same lucid spots in sections crossing calcite-filled cells are very deceptive, appearing like pores. In clay-filled cells they appear clearly as parts of the wall. They interrupt the median wall and confuse in color with the outer laminæ, these lighter parts being also of the same color as calcite infiltration; hence the deception in the fossil.

Fistulipora carbonaria Ulr. is of common, massive growth. Its autocells are rounded, with here and there one having a slight distension, as if a lunarium was developed with minimum distinctness. The autocells are separated by angular, large mesopores in single series, except in the clusters or maculæ, where they are more numerous. The walls around autocells are thick, while those between mesopores are very thin, low, and scarcely above the last tabulæ; hence the appearance is that of isolated autocells with raised "peritreme." Longitudinal section shows the mesopores to have arched, numerous tabulæ, appearing thus as vesiculose filling, or "cœnenchyma" between the autocells. New autocells arise abruptly, displacing one or more mesopores in the midst of mesopores, *i. e.*, "cœnenchymal gemmation."

Stellipora antheloidea Hall encrusts shells, etc., growing laminar or massive, a centimeter thick. The surface is crowded with stellate monticules about 2.5^{mm} wide, each consisting of a central, six to twelve-rayed, depressed, quite smooth, macula, and around this, between its rays, an equal number of ridges which are highest at the inner end and slope outward to the interspace. Sometimes additional ridges occur midway between the outer ends of the primary ones. The maculose area, as proved by sections, is composed of large, angular mesopores, and the ridges exclusively of rounded autocells, these tending to arrange in two rows, with the walls between the rows a little raised and straightened. The space between monticules is small and occupied by mesopores around a few single autocells, and groups of two, three, four, etc., cells or incipient ridges. In longitudinal sections the close tabulæ only distinguish the mesopores at first, but they soon become vesiculose.

This description is taken from specimens from the "Trenton shales" of the Northwest. The species is very rare as compared to the acrogene ones generally called *Constellaria*.

DISCUSSION OF TREPOSTOMATA

A few species suffice to illustrate the general characters of Trepostomata, and the further detail may be explained by them. In this manner of beginning with a few representative species, proceeding thence to the study of the several characters recurring in the whole group, the perplexing taxonomic definitions may be obviated.

The growth habit or zoarial form is fairly constant in the species, but very various beyond that taxonomic limit. The approximately hemispheric zoarium, with its cells radiating and multiplying with growth from an initial point, may be taken as the central or composite or primitive type. Next, species with an established tendency to grow fastest around the base develop the flattened massive type. Others, more perigene in degrees, connect with the laminate or encrusting, in which perigene growth is near its practicable extreme.

On the other hand, the hemispheric form, by increased acrogene growth tendency, becomes the digitate, and finally dendroid branched. But, as a rule, the acrogene zoarium has a perigene basal expansion, and every degree of form might be pointed out from the conical (Pl. A, Fig. 7), in which moderate acrogene and perigene combine, to the strongly acrogene form, with more or less extremely perigene basal (Fig. 5). As to the basal expansion, it may be massive, laminate to encrusting. It may in some species support two or more acrogene growths, and in just these cases also the acrogene part may be small or wanting, arguing that the basal expansion might have been the origin of some strictly perigene species, the acrogene part being wholly suppressed. The laminate form may have again become massive. Finally, an acrogene growth may be round, compressed, flattened, frond-shaped, or bifoliate. In short, the series between zoarial forms is very complete, and genetic relationship between the most extreme forms may be presumed. The lines of evolutionary development have never been traced, however, and they evidently cross or parallel in a confusing manner; hence this character is of taxonomic use in species chiefly.

The different zoarial forms result not from changed shape and size of the component cells, as one can readily observe in similar zoaria of extremely different cells, but, as seen firstly in variations of a species, it results from increase of cells, the region of greatest cell increase being that of greatest zoarial growth, and inversely. The change of zoarial form, nevertheless, must be made to explain the change of cell as seen in different regions in the same species. Thus, in the acrogene growth, where the cells are turned from the axis of rapid growth to the peripheral slow growth region, it changes markedly, becoming thick walled, closer tabulated, etc. (Pl. A, Fig. 6, *c*). Noticing that the cell apertures do not spring apart under any circumstances, and presuming that this is because the respective zooids were bound together by a cortex, it can be understood how the same cell can be different in two parts, and why there are certain differences in cells. Thus, the tip of an acrogene zoarium, like a hemispheric or massive zoarium, has the cells subparallel, lengthening as new cells develop, so that the surface or circumference widens and the radius or cell-length increases proportionately. But as a cell turns into the peripheral region it comes into a zone of more restricted circumference and radial lengthening; hence the cell is shorter, thicker-walled, and closer-tabulated. Moreover, the cell-increase lessens to some degree, which further restricts the circumference and radius with added effect. In the latter way the apex of branches often retarded building thick-walled and close-tabulated cells, and sometimes the basal expansions did likewise; and it is evident then that a kind of zoarial maturity exists, simulating if not derived from the "peripheral" stage. Further, specimens in which a mature stage has developed at the apex may renew axial growth and cell characters, a second maturity following, by which it would seem that environmental causes have had to do with the time of maturity.

In a specimen of *Eridotrypa mutabilis* Ulr. at hand, a fortuitous branch has arisen from the mature region instead of the axial, and consequently a cell can be traced as axial, peripheral, axial, and peripheral again. Injured or broken zoarial parts are commonly renewed by thin (axial) cell growth, even in the peripheral region, a stolon-like expansion first overspreading the dead area. In perigene growth also the young cells arising at the margin are at first more prostrate than later, giving rise to a basal stolonal region, and in thin, laminar, or encrusting forms it is very distinct. In these cases the stolonal has been said to be probably the homologue of the axial immature region of dendroid zoaria. The stolonal and immature regions in these may coincide, but it is wrong to assume that they do in other and all cases. The stolonal part need not be considered as coördinate with the developmental peripheral and axial regions. It seems, in fact, unnecessary to attach any genetic significance to the stolonal region further than that it is incidental to perigene growth.

In a given species one specimen larger than the other may be so either from more vigorous growth, as seen in larger axial or immature region, or from longer continued growth, as seen in thicker peripheral or mature region.

Cell increase is, as a rule, intermural, *i. e.*, young cells begin as small, round pits in the wall at the angle between three or more older cells. The reproduction or budding of zooids doubtless took place in the cortex above the zoarial skeleton, and only later the young zooid comes to build a cell, which, however, from its initial, has its own wall, *i. e.*, wall-half. The young cell becomes triangular, quadrangular, etc., in proportion as it grows large enough to neighbor on three or more cells. Young cells have shallower calycals and are generally closer-tabulated, but proportionate to their size, as compared to mature ones. The number of young cells in proportion to large ones affects the cell pattern at the surface. This is especially notable when the simplest case of rapid, direct, continuous expansion of young cells is contrasted with that where "mesopores" are numerous (Plate A, Figs. 1 and 10).

Mesopores are said to be present if the young cells when about half-grown in diameter, retard or cease their expansion, but, of course, continuing length growth. If the mesopore stage of cell is short, few mesopores, if long, many mesopores, are present. They may outnumber the autocells so greatly that a small proportion only could become autocells. They may be more numerous in the peripheral, mature, or retarded cell growth region. Again, as in *Prasopora simulatrix* many mesopores remain such while other newer ones develop to autocells. Yet, apparently any mesopore may finally become autocell. They are, however, something more than retarded young cells, in case like *Stellipora* (*Constellaria*), where the angular mesopores are rather larger instead of smaller than the rounded autocells.

The more distinct the mesopore development the more subordinate they appear to become. The autocells are angular from contact with each other or young cells, but rounded when crowding mesopores, the latter alone remaining angular. Also the mesopores become shallow, the tabulæ developing close to the wall margin forming "closed" mesopores, or they even filled solid with superimposed tabulæ; or the tabulæ overlap the walls, forming "vesiculose" structure. Autocells arise, displacing several mesopores at once, "cœnenchymal gemmation," in some species with vesiculose or even regular mesopores.

Monticules, as Nicholson pointed out, are rapid cell increase areas. In simplest cases they appear at the surface as mere small elevations or more or less elevated clusters of slightly larger sized cells, among which young cells are seen except rarely in a growth retardation stage. A few young cells or mesopores are present, or many mesopores, or again aggregated mesopores between the cells are found in some species, or exclusively mesopores form maculæ or large aggregates in other species, with or without surrounding major-sized autocells. The elevated clusters are the typical *monticules.* The extreme degree of elevation is expressed by the name monticule. Maculose ones or "maculæ" are nearer plane or slightly depressed. Exceptionally a typical monticule may extend like a ramulet, in which case it is probably to be considered as such,—a fortuitous acrogene growth having sprung from the area of one monticule as it might also have from that of several.

The monticules are distributed on the zoarial surface more or less regularly, new monticules arising from the widening intervals, and never, apparently, one monticule from another. The function of the zooids that built the major autocells is unknown if it was different from that of others. The only discernible peculiarity of the monticules to which a special function could be assigned is their more rapid reproduction or cell increase than the interspaces. In this respect they resemble the acrogene growths or the axial region, and when very prominent they might suggest an origin as retarded branches, but no unquestionable transitional forms to these are known to me. They differ from branches in their size and in relation to the zoarium as a whole; for, if monticules produce the more new cells, their interspaces produce the less, the zoarium being unchanged; while, on the contrary, growth of branches comprises essentially the zoarial growth as well as the maximum increase of cells.

The surface pattern, as shown, is very diverse. The average size of cells in a species is quite constant, but in different species differs several diameters. The form of aperture, quadrangular, polygonal, to rounded; the relative size and numbers of young cells and mesopores; the monticules and maculæ of varied style; all these form conspicuous essential characters by which species can be recognized. The calycals, too, are deep or shallow, relatively, in different species. The autocell walls, which are thin and then more or less thickened, give respectively polygonal or rounded calycals, since the thickening is greatest at the cell angles. A beveled wall edge or impressed rim around the cell aperture gives it in many a saucer-shape, especially when the walls are very thick (Plate A, Fig. 11).

Acanthopores or warts may be present on the walls, usually at cell angles. A lunarium, when present, gives the cells another peculiarity. The lunarial wall and the acanthopores are, however, mural modifications, and will be explained in that connection later.

Thin section is quite necessary to bring out the wall's structure. The walls are dense. If thin they may show no differentiation; yet, if a specimen split, the cleavage may pass longitudinally and so as to leave part of the wall attached to each stone core, which fact has been taken to indicate that the wall is always structurally double! Presumably the wall is built double always, *i. e.*, the increment on the margin is continued within every calycal, the wall being thus double with a median, third part, which is, however, not known to be double. A thickened wall tends to show greater differentiation, both in structure and composition, than a thin one. The median wall may appear either distinct or not, and correspondingly the striping parallel to the wall's surface when seen, showing the laminæ of growth, is either interrupted by the median wall or more or less distinctly crosses continuously from one side wall to the other.

To explain the structural aspect of acanthopores in thin sections, the following analysis may serve. A distinctly double wall shows the median wall as a line in transverse section (Fig. 1, *a*) and when the wall edge is scalloped (Fig. *b*) the median line appears interrupted in section (Fig. *c*), corrresponding to the angles. A rounded wart (Fig. *d*) would produce a similar effect (Fig. *e*); or, if very distinct, as in Fig. *f*. When once begun, the wart may have its own growth, so to say, independent of the wall thickness (Fig. *g*), becoming so large as to appear to have displaced a young cell or mesopore. Such a large acanthopore inflects the cell wall, forming a vertical rib or pseudoseptum as a rule. No doubt the acanthopore end, or wart on the wall, extended to fill an invagination in the web or cortex which bound the zooids to which the cells belonged. Explanation of the cause of such invagination need not be attempted here. But it may be added that the walls were evidently built by surface secretion, and that the growth of a projecting wart would be accumulative as compared to a plane surface, other things being equal. This may explain why acanthopores are often so independently large. A scalloped or saw-edged wall would not develop so. The transverse of a wall would, however, if the zooids and cortex did not draw upwards fast enough to prevent it. Thus a wart thickens in two dimensions to the wall's one. Since, however, the wart is on the wall, it receives below the wall thickness also, and hence acanthopores might well be four or more times the thickness of the wall from result of secretion alone. In fact, it is necessary to explain why the walls, etc., can be very thin, which is evidently because the zooids drew forward rapidly.

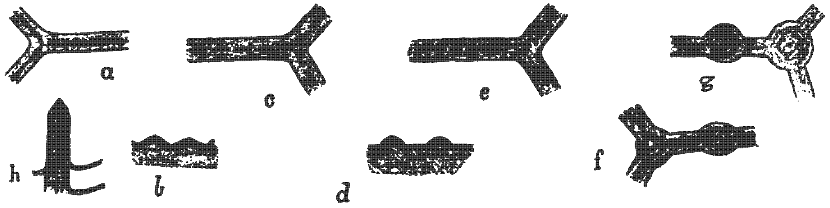


FIG. 1.

It is fair to presume that structural differentiation of the wall may be accompanied by difference in composition; and that may explain why the elevated lunarial wall may be different colored and textured than the main wall; or, again, lucid vertical lines or "lunarial tubuli" only are different, these being the vertical extensions of tooth-like elevations on the lunarial wall margin. Acanthopores show similar differences. Such structures might be mistaken for mural pores in thin sections. Mural pores do not occur.

Tabulæ perhaps need no special mention; their character as the successive bottoms of the calycals is entirely evident (Plate A, Fig. 2, and Fig. 1, *h*, p. 21). In structure, if any be seen, they are one-sided. E. O. Ulrich has observed the very rare occurrence of perforation or circular opening in the last tabula, which he interprets to prove that all other tabulæ are double, comprising the amalgamated cover of one zoœcium and bottom of a next superimposed zoœcium. In absence of any substantiating evidence it is better to take the most direct explanation, which would be that the observed perforated tabulæ were left incomplete by the death of the colony. Indeed, in *Hemiphragma*, the tabulæ of the cells in the peripheral region are all left incomplete or were imperfect as to calcareous structure. The surfaces of tabulæ are sometimes papillated, and these again, like the acanthopores, simulate perforations in the fossilized specimen.

As a rule, neighboring cells do not have corresponding tabulæ, either in position or number. In any species or individual they are approximately regular in position and numbers, but never quite so. In different species the number ranges in extremes from none, as seen in the axial region of some species, to very many in others, or even to a compacted papillose mass filling the cells, or especially the mesopores in some thick-walled forms. There is no unit form and size of loculus assignable, which argues very strongly against any theory that the successive loculi represent superimposed zoœcia. The clearer interpretation is that each cell was built by one zooid. Tabulæ are, as a rule, very thin; and tabulæ wanting and tabulæ thickened are opposite degrees. Individual variation and specific difference in number and thickness of tabulæ may be ascribed to difference of growth and to secretion of substance. Difference in form, such as the cystiphrams (*Prasopora*), are ascribable to shape and size of the zooids' base; and vesiculose mesopores, to shallow or closed calycals from short zooids, and to their shifting, possibly, also.

AFFINITIES OF TREPOSTOMATA

Regarding the affinities of the Monticuliporoidea as a whole, the evidence uniting these to the Bryozoa on the one side, and to Tabulata or Alcyonarian corals on the other, does not lead to a compromise conclusion that they really were related to both as an intermediate or connecting link, because, as will be seen, the interpretation of the zoarium necessary to unite them with the one is discordant to that necessary to unite them with the other; and because of evidence to the contrary from the embryology of living Bryozoons and corals. Discussion is therefore confined to the question whether the extinct Monticuliporoidea are Bryozoa or Cœlenterata.

In relation to Bryozoa, the problem begins with the Trepostomata section, some or all of which have been variously and doubtfully referred to Cyclostomata; and this order of Bryozoa is extant. The reference involves comparison with the supposed Cyclostomatous genera *Neuropora* and *Heteropora*, of which we are yet uncertain. Gregory[1] refers these as typical Trepostomata, not Cyclostomata. The question rests mainly upon the fossil and recent *Heteropora* which Nicholson[2] has thoroughly discussed and which, as it appears, simulates Trepostomata, but has many transverse mural pores and other differences. Trepostomata must therefore be proved to be Bryozoa and *Heteropora* likewise to belong to Trepostomata, before they can be united with assurance. Gregory's reference needs proof and affords no evidence, but expresses well perhaps that we are uncertain of all. Passing to the comparison of Trepostomata with undoubted Bryozoa, this requires knowledge of the extinct Cryptostomata, which must in turn be compared with Bryozoa; and discussion of that part of the problem will therefore be deferred to the section on Cryptostomata.

In relation to Tabulata or Alcyonarian corals, Trepostomata may be compared immediately. In the first place, such forms as *Monotrypa* compare with *Chætetes*, a massive zoarium of small, tabulated, thin-walled, polygonal cells. *Chætetes* has comparatively lighter colored, probably more calcareous walls. Its cells increase only by fission, while intermural "budding" obtains in *Monotrypa*. It is said, however, that fission occurs rarely in Monticuliporoidea, which leaves a difference in degree only between these two. *Chætetes* is extinct, but is referable only as a coral. It indicates that the *Monotrypa*, *Monticulipora*, etc., are corals; but that the family *Chætetidæ* should contain *Monticulipora* seems doubtful when *Fistulipora* is placed in a family of its own.[1] Certainly *Prasopora* does not belong in both.

---

[1] Catalogue of Jurassic Bryozoa, p. 193, 1896.

[2] Structure and Affinities of the Genus Monticulipora, p. 62.

Fistulipora, which is the extreme form of Trepostome as compared to *Monotrypa*, is the very one most approaching the Recent coral, *Heliopora*, which, as shown by Mosely, is an Alcyonarian, with a true tabulate skeletal structure. *Heliopora* has the larger cells, but like *Fistulipora* has autocells among mesopores, called siphonopores. The autocells increase by "cœnenchymal gemmation," *i. e.*, a young autocell arises among siphonopores, displacing several. Siphonopores and mesopores are alike. Also, in the mature region of *Heliopora*, the walls thicken and a wart-like projection stands generally at the siphonopore angle and twelve of them surround the autocell. Structurally the warts are similar to "acanthopores," but the wall of *Heliopora* is highly calcareous, and in thin section one sees primarily the crystalline structure radiating from the normal line or center, while the Monticuliporoid wall, being apparently less calcareous, shows the organic lamination, and the acanthopores have concentric structure. The difference is referable to the degree of calcareous deposit in which all corals differ. The warts on *Heliopora* are due to transverse canals between zooids swelling the cortex unevenly. Acanthopores might well be of like origin, and if so they indicate a canal system like that in Alcyonaria.

It has not been clearly enough understood that Mosely[2] demonstrated the *Heliopora* to have no mesenterial septa, but that twelve vertical ribs in each autocell are pseudosepta; and as such they can be compared exactly with the inflections produced by acanthopores in many Monticuliporoids, if the small difference in calcareousness of skeleton be considered. More calcareous ones have sharper processes. A lunarium is wanting in *Heliporidæ*, but this structure is absent in *Fistulipora* in part, and in most Trepostomata. Any structural differences between *Heliopora* and *Fistulipora* are found further in some genus or other closely related to the former, except the monticules or maculæ of the latter.

---

[1] EASTMAN, op. cit., pp. 102, 103.

[2] Challenger Report.

If one places all Trepostomata and the Tabulata (Alcyonaria) together, they are compared as follows: The largest cells of the former are scarcely equal the smallest autocells of the latter. Growth habit is alike. Cells, monomorphic or dimorphic, are alike; except that distinct pseudosepta in autocells are common in Tabulata, being absent in few cases and these when the walls are very similar in structure to that of Trepostomata, *i. e.*, when crystalline radiate striping is absent,—except also that mural pores cross the walls of many Tabulata, not, however, in dimorphic forms nor in monomorphic ones with small cells,—except again, the lunarium of Fistuliporidæ and the so-called dorsal septum of Alveolitidæ. Notably, the two lunarial angles, forming two pseudosepta, are on the upper side in the former, the single "septum," pseudoseptum, is on the lower side in the latter; the structures therefore not corresponding. If, however, they be ascribed respectively to the double ventral folds and the single dorsal fold of certain Alcyonarian Recent corals,[1] one finds them all represented in Cœnites, a Paleozoic tabulate coral. They are rarely indicated in skeletal structure of either Monticuliporoidea or Tabulata, but argue Alcyoranian affinities.

Cell increase is not unlike. In the Tabulata (Alcyonaria) it is by fission, unequal fission, stolonal gemmation, and intermural gemmation, which are probably degrees of transformation.[2] Intermural gemmation is the rule in Trepostomata. The peculiar cell development known as cœnenchymal gemmation occurs in both, and they are not distinguished.

---

[1] See further, Neues Jahrb. Minn. Geol. and Pal. Beilb. X, pp. 316, 320.

[2] See op. cit., pp. 281, 359.

But Trepostomata generally have *monticules* or maculæ, which Tabulata never have; and therein is the one important distinction. But this also argues their relationship, for the Tabulata, comprising three divisions, can be held as the Paleozoic ancestors and representatives of the Alcyonaria as to three of four divisions respectively, the fourth having no known ancestor, unless the Monticuliporoidea be so considered.[1] Among those of the fourth division *Renilla et al.* show a budding and grouping of the dimorphic zooids similar to or like that which must have obtained in the monticulate *Prasopora et al.* The absence of tabulate skeleton in *Renilla* would be explained as in the case of other Alcyonaria, and need not be recounted here. The supposed relation of Monticuliporoidea and Pennatulidæ I formerly considered as based on deduction and slight evidence, and the explanation of monticules is corroborative.

These same monticules and maculæ, on the other hand, bind the Monticuliporoidea together, *i. e.*, Trepostomata to Cryptostomata. In the preceding paragraphs the relation of Trepostomata to Alcyonarian corals is discussed without the Cryptostomata, but these would not change the argument as given if included. They are generally supposed to be Bryozoa, and are important to that side of the question which will be given later. There is in fact no character in the Monticuliporoidea to separate them from the Tabulata, corals. Their separation, if accomplished, would rest upon stronger evidence binding them to undoubted Bryozoa.

EXPLANATION OF PLATE A

FIG. 1. Monotrypa magna Ulr., cell pattern. × 10.
FIG. 2. Monotrypa magna Ulr., vertical section of cells. × 10.
FIG. 3. Diplotrypa limitaris Ulr., cell pattern. × 10.
FIG. 4. Diplotrypa limitaris Ulr., vertical section. × 10.
FIG. 5. Callopora multitabulata Ulr., a small zoarium, natural size.

---

[1] Op. cit., p. 349.

FIG. 6. Callopora multitabulata Ulr., *a*) cell in axial region, *b*) vertical of same, *c*) vertical showing peripheral cell region, *d*) cell pattern of peripheral region. × 10.

FIG 7. Prasopora simulatrix Ulr., zoarium, natural size.

FIG 8. Prasopora simulatrix Ulr., cell pattern. × 10.

FIG. 9. Prasopora simulatrix Ulr., vertical section. × 10.

FIG. 10. Batostoma fertile Ulr., *a*) cell pattern × 10, and *b*) surface. × 20, showing mesopore' stabulaæ.

FIG. 11. Eridotrypa mutabilis Ulr. surface × 20, showing calycals. After Ulrich.

FIG. 12. Anolotichia impolita Ulr., cell pattern. × 10.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.,
November 5, 1900.

THE EXCURSION TO THE PYRENEES IN CONNECTION WITH THE EIGHTH INTERNATIONAL GEOLOGICAL CONGRESS

THE origin of the ancient crystalline rocks of the earth's crust is a subject which has always possessed a peculiar interest for geologists and which, now that the progress of investigation seems to bring the solution of the various problems connected with these rocks almost within our reach, has a greater attraction than ever.

One of the most important lines of evidence bearing upon this question is that derived from the study of the contact zones about intrusive masses, but the effects produced by many of these intrusions have been differently interpreted by different observers.[1] In France especially, Michel-Lévy, Barrois and Lacroix have described intrusive granite masses, which have not only intensely altered the strata through which they pierce but which have produced a wholesale transformation of the sedimentary rocks in question into granite, the granite now occupying the space formerly occupied by the sediments. If this be the origin of granite, a knowledge of the fact would have an important bearing on the interpretation of many occurrences in the Archean, but the great majority of geologists have been unable to find evidence of it in their respective countries. The French Pyrenees have, however, been cited by Lacroix as a district in which these remarkable transformations could be seen with especial clearness, and in connection with the International Congress of Geologists held last summer in Paris, an excursion to the Pyrenees was accordingly arranged, under the leadership of Professor Lacroix, in order that the members of the congress might have an opportunity of seeing these transformations in the district made classic by Professor Lacroix's work. It is proposed in the present paper, first to give a short account of this excursion and then to discuss briefly some points in connection with the explanations offered by Lacroix of the phenomena observed.

---

[1] ADAMS, F. D.: A review of some recent papers on the Influence of Granite Intrusions upon the Development of Crystalline Schists. JOUR. GEOL., Vol. V, 1897.

Leaving Paris on the morning of August 3d on our way south to the rendezvous of the excursion at Ax-les-thermes, the great Tertiary plain of northern France was first traversed. The country as far as the eye can reach is quite flat and excellently cultivated. The grain had just been cut and stacked, and the country in appearance afforded a marked contrast to those portions of the southeast of England underlain by rocks of the same age, in the entire absence of the picturesque hedges and of standing timber. The train then gradually ascended the table land of the Plateau Central, from which far to the east rose the volcanic peaks of the Auvergne, and the country assumed a more rolling character. Descending from this plateau on its southern side over strata of Jurassic age, past Brive and Souillac, the landscape underwent still another change, the country becoming in many places rough and broken, with great exposures of bare rock on either side, through which the train threaded its way in numerous tunnels and rock cuttings, and as the night closed in reached the old city of Montauban. Next morning, passing over the Tertiary basin of southern France, through Toulouse and up the wide low walled valley of the Ariège, Foix was reached, about which place the valley narrowed and the foothills of the Pyrenees rose high and abrupt on either side. Thence passing on by Tarascon the train reached Ax-les-thermes, a picturesquely situated little town, lying well within the Pyrenees, whose hot springs and baths annually attract a large number of visitors, chiefly from other parts of France.

Here the members of the congress who were to take part in the excursion, twenty-eight in number, coming from various parts of Europe and America, were received by Professor Lacroix. Five of the party only claimed English as their native language; Mr. Arnold Hague, Professor Wolff and Dr. Ries representing the United States, while Mr. Kynaston, of the Geological Survey of Scotland, represented the United Kingdom.

The following day, August 5th, the regular work of the excursion began, two visits being made, from Ax-les-thermes as headquarters, on consecutive days, to the contact of a large mass of granite, several miles to the northeast of Ax-les-thermes in the heart of the Pyrenees, with a series of shales and limestones believed to be of pre-Cambrian age. The exact age of the granite is not known but it is younger than the Carboniferous and older than the Lias.

The contacts seen on the first day, were chiefly in the vicinity of the beautiful little L'Etang de l'Estagnet, from which there rise on either side great walls of bare rock, and well graded talus slopes affording abundant exposures. (See Figure 1.)[1] The normal granite of the district is light in color, poor in iron magnesia constituents and contains large porphyritic feldspars. It often shows marked evidences of dynamic action. The shales near the contact are hardened, being converted into a hornstone, said by Lacroix to be in many places "feldspathisé," but the most interesting feature of the excursion was the contact of the granite with the limestone. This limestone, which is gray in color and highly crystalline, contains many little bands of silicates, representing impure laminæ in the original rock, which, especially on the weathered surface, emphasize its stratified character in a most striking manner and often display the most complicated contortions. The limestone in its whole character and appearance exactly reproduces many occurrences seen in the more altered limestones of the Hastings Series in the Archean of Canada.

Between the limestone and the granite, however, there is a zone of rock, often very narrow but in some places, according to Lacroix, as much as 800 meters wide, more basic than the granite and termed by Lacroix, "Diorite" or "Roche Dioritique." This completely surrounds certain isolated occurrences of limestone and is believed by Lacroix to have been produced by the granitic magma, before crystallization, dissolving a portion of the lime-stone, incorporating it, and thus being rendered more basic, crystallizing out as a diorite about the contact. This "Roche Dioritique," while as a general rule tolerably uniform in appearance, often presents rapid variations in size of grain from fine to coarse, and in other places passes into more basic forms such as norite and even into varieties holding olivine.

---

[1] For the photographs which illustrate this paper, with the exception of that reproduced in Fig. 2, the author is indebted to Professor Heinrich Ries, of Cornell University.

The excursion of the second day took the party to another portion of the periphery of the same granite mass in the wild district about the L'Etang de Baxouillade (see Fig. 2) and the Cirque de Camp Ras. The route followed led first over the granite, which as the contact was approached was seen to hold a few dark inclusions, which certain of the petrographers present at once set down as basic secretions from the magma. These, as the little L'Etang de Baxouillade was passed become more numerous and often presented the appearance of having been softened and drawn out. Further on at the Cirque de Camp Ras the granite comes against a mass of shale interstratified with limestone. Both of these rocks are highly altered, the shales being converted into dark hornstones and the limestones into paler lime hornstones, consisting chiefly of a basic feldspar and pyroxene. Along the immediate contact of the granite, there appears to be evidence that the dark inclusions before mentioned are masses of hornstone which have been separated from the walls, caught up by the granite magma and more or less softened —or in the case of the lime hornstone dissolved, giving rise to irregular shaped masses of the "Roche Dioritique" before mentioned. One block of gneissic granite about two feet long was observed, at one end of which, embedded in the granite was a mass of the light-colored hornstone enclosing a mass of unaltered limestone, while at the other end of the same block, the granite contained small masses of "Roche Dioritique," which certainly presented the appearance of dissolved fragments of the same limestone. The only other explanation of the origin of these darker-colored masses in the granite is that they are basic secretions from the granite magma itself, about the margin of the mass, but the appearances in the field rather favor Lacroix's interpretation.

The next day the party, leaving Ax-les-thermes, drove to Foix, visiting on the way the gypsum quarries near Tarascon. The gypsum is of Triassic age and is seen to have resulted from the alteration of anhydrite. It contains intercalated marly beds holding dipyre, tourmaline and other minerals, which are believed to have been developed in them by an intrusion of ophite, which however is not exposed in the immediate vicinity.

On August 8th a visit was paid to a great mass of "Cipolin," intercalated in the gneiss near Arignac, which is locally rich in various minerals of the humite group and containing also spinel, plogopite, rutile, etc. The name "Cipolin" is given by the French geologists to any crystalline limestone intercalated in gneiss, even although it be free from the micaceous minerals which give to the typical "Cipollino" its distinctive character. This mass is from 200 to 300 meters wide and is identical in character with the limestone found in many parts of the Laurentian in North America. The enclosing gneiss is said by Lacroix to contain garnet, and also to differ somewhat in other respects from the granite of the vicinity of Ax-les-thermes. Its origin is unknown.

In the afternoon other large exposures of crystalline rocks near Cabre were visited. These consisted of epidosite, quarried for road metal, containing large lumps of malacolite in places and traversed by little graphite seams. This epidosite is believed to be an altered limestone, and is interstratified with bands of a peculiar dark fine-grained micaceous gneiss, exactly like that which is so uniformly associated with the limestones of the Laurentian in Canada and in the Adirondacks. The age of these crystalline rocks has not as yet been determined.

In the evening the party reached Vicdessos, some seventeen miles west of Ax-les-thermes, a most picturesquely situated little mountain village, from which excursions were made on the two following days. Our route on the first of these days led up to the quaint little village of Sem, where the renowned iron mines of Rancié were visited. The deposit here consists of a large body of limonite of irregular shape, enclosed in Silurian limestones and shales, and nearly coinciding with them in dip. It is worked by a series of levels the lowest of which is at Sem. This ore body which is very extensive has been mined for ages and formerly supplied ore to as many as fifty Catalan forges, which were in blast in the vicinity. The ore which is handled in a rather primitive manner is now sent to Tarascon, where it is smelted in the blast furnaces situated there. The limonite which makes up the mass of the deposit that has been worked up to the present time, is derived from the alteration of spathic iron ore into what the ore body changes in depth.

Taking a little path up the mountain beyond Sem, a summit marked by the Croix de Ste. Tanoque was reached, where an occurrence of lherzolite is well exposed. This is the original locality of the "Lherzoline" or "Lhercoulite" of Cordier, who mistook the somewhat altered and serpentenized rock for a distinct variety, to which he gave this name. The Jurassic limestones are here penetrated and altered by the intrusion, being bleached and crystallized, while the blocks of the light colored dipyre hornstones found near the contact are considered by Lacroix to be impure or marly bands which were interstratified with the limestones and which by virtue of their peculiar composition were able to fix the exhalations from the lherzolite, which the limestone was unable to do, and in this way to yield a rock rich in dipyre, microline, orthoclase and a variety of other silicates, the original differences in the composition of the beds becoming accentuated through the action of selective metamorphism.

Leaving Vicdessos the following morning, the party traversed the forest of Freychinède, climbing up great exposures of the Jurassic limestone, blue in color and often brecciated, the color being bleached out in spots and streaks precisely as in the Jurassic limestones of the Alps. In these limestones are several occurrences of lherzolite and ophite, which according to Lacroix have the form of laccolites, and which alter the limestones as described in the case of the occurrences near the Croix de Ste. Tanoque. Passing out of the forest and over the high pastures of the Col de Massat, where a number of shepherds and and cowherds in their picturesque dress were met, the party descended to the renowned L'Etang de Lherz, a beautiful little tarn, by the side of which the original lherzolite is seen. Here a great mass of this rock, dark brown on the weathered surface, penetrates the Jurassic strata, forming by far the most important occurrence of lherzolite in this portion of the Pyrenees. After lunch by the shore of the lake, the mist which had been gathering during the morning settled down as rain, and the party were obliged to hurry on to Massat, the "chef-lieu" of the canton, one of the most secluded little places in the Pyrenees, and one of the few places where the peculiar local costumes of the peasants of the Pyrenees still survive.

From Massat, early on the morning of August 11th, the party drove to Saint-Girons, stopping on the way to examine two or three ophite occurrences and at the Pont de Kerkabanac to see a contact of granite with schist. On the rocky bank of the little stream at this point the granite is seen breaking through the schist and including many little fragments of it. These are often angular, but in some cases appear to have been softened and somewhat drawn out. The "granitization" of these schists was said to be particularly pronounced. The appearance of the contact, however, was like that of any other ordinary granite contact, where the igneous rock has broken through a shattered mass of shale, caught up the fragments and baked them intensely.

At Saint-Girons the train was taken to Bagnères-de-Bigorre, another locality in the Pyrenees renowned for its thermal springs and hot baths, where during the afternoon the party visited the museum of Mr. Charles Frossard, rich in collections illustrating the natural history of the Pyrenees, after which they inspected the extensive marble cutting works and the baths.

About two miles from Bagnières-de-Bigorre is Pouzac, the well-known nepheline syenite locality. This rock, together with two masses of ophite, is exposed by the side of the railway line, cutting a series of limestones interstratified with marls, which is supposed to be of Triassic age. But little can be seen of the mutual relations of the several rocks or of their contacts. Lacroix states that the nepheline syenite and the ophite appear as little masses penetrating the Triassic limestones. He thinks the nepheline syenite is later in age than the ophite, which seems to surround it, but there appears to be no evidence from their field relations which makes it improbable that they are differentiation products of the same magma. The occurrence of the nepheline syenite, from which all the Pouzac material in collections the world over is derived, is barely sufficient in size to furnish a working face for a single small quarry. (See Fig. 3.) The rock is much decomposed, the sandy disintegration product being used for repairing the roads in the vicinity, but fresh material may be obtained from the numerous bowlders of decomposition. Small bostonite dikes occur in the limestone near the contact. The marly beds are filled with dipyre and the limestones contain little albite crystals, both minerals being attributed to the metamorphosing action of the ophite. The ophite itself is in many places filled with dipyre, which is, however, believed by Lacroix in this case to be the result of weathering.

On leaving Bagnières-de-Bigorre the party drove up the valley of Campan to Payole, a remote hamlet in the mountains, near which a quarry has been opened in a marble of Devonian or Carboniferous age, the stone being sent to Bigorre to be sawn and polished. The rock, which is known as Marbre de Campan, has a reddish or a grayish color and a linear brecciated structure, which produces a handsome effect on the polished surface, and which appears to be caused by certain laminæ in in the rock, rich in carbonate of lime, breaking apart under the pressure to which the rock has been subjected, while the intervening laminæ, rich in argillaceous matter and more plastic, have been forced in between the calcareous fragments and now cement these together.

One of the most interesting granite contacts seen on the excursion was reached from Payole, that, namely, of the Cirque d'Arbisson. Leaving Payole early in the morning on August 13th the party made their way through the Bois d'Arreiou-Tort and up over the moraines mantling the valley bottom and the lower slopes, and after several hours climbing reached the foot of the great Cirque. But little rock is exposed on the way up, but at the Cirque itself, whose walls tower up in the form of a great amphitheater of bare rocks skirted with talus piles, the exposures are magnificent. (See Fig. 5.)

The rocks composing the Cirque are Upper Devonian in age and consist of thinly banded strata, greatly contorted and twisted, and now converted into hornstones of several kinds, varying in character with the original composition of the rock. The unaltered rock was not seen, but it would seem to have been not unlike that worked in the quarries near Payole. The argillaceous bands, however, were probably more numerous and some of the bands were highly siliceous. The contortions and the breaking apart of the harder bands with flowing of the relatively softer layers, in this case the limestones, between the fragments is excellently seen. (See Fig. 6.) The original marly beds have been converted into epidote hornstones, while the more siliceous beds are converted into a flintlike material which is much darker in color. Some of the limestone bands, although greatly contorted, have retained their fine-grained texture and blue color, but owing to the shearing movements to which they have been subjected they have assumed, as is frequently the case in such occurrences, a sort of schistose structure. The limestone, however, is usually traversed by little streaks, coarser in grain and whiter in color, marking the first stage of a recrystallization and passage into marble. The limestones or calcareous bands in places contain large crystals of red garnet, resembling the well-known occurrences on the Stikine River, although the development of the crystals is not so perfect. Beautiful flat rosette-like groups of vesuvianite crystals also occur in places along the bedding planes, usually between the layers of epidote hornstone and the more siliceous bands. A few granite dikes and a mass of granite, apparently of comparatively small dimensions, occur on one side of the Cirque, while the other side is free from granitic intrusions. In these dikes, and also in the hornstone near the contact, axinite occurs in masses of considerable size. In the dikes this mineral occurs as rather coarsely crystalline streaks, in some cases on the walls and in others within the dike itself. In the hornstones it occurs as an impregnation, apparently partially replacing the other constituents of the rock. The petrographical character of the various rocks can be well seen in the immense talus piles at the foot of the cliffs, which also afford an excellent opportunity for collecting. From a petrographical standpoint this was one of the most interesting localities visited on the excursion.

The excursion, as originally planned, was to have terminated here, the party returning to Bagnières-de-Bigorre and then taking the train to Paris; but the majority of the party willingly accepted the proposal made by Professor Lacroix to extend the excursion by another day and visit Barèges. Accordingly, they left Payole on the morning of August 14th, and drove to Gripp, and thence walked to the Col du Tourmalet, over a great series of highly inclined and more or less altered clay slates, limestones, etc., of Upper Silurian and Devonian age. Magnificent views of the Pic du Midi, the highest point of the French Pyrenees, were obtained at a number of points along the route. The ascent was long, the day very hot, and shade by no means so abundant as could have been wished, but the Col du Tourmalet was at length reached, and the very abrupt descent made into the valley of the Bastan, over magnificent rock exposures. The granite appears near the head of this valley, and at its contact with the stratified series there appears a mass of rock consisting of a mixture of actinolite and axinite. The contact was not seen by the writer, but Professor Wolff, who saw it, states that the margin of the granite seemed to be well defined, although somewhat melted into the actinolite axinite rock above mentioned. As the evening was closing in, however, there was not sufficient time to make a study of the relations of the intrusion, the party being obliged to press on to Barèges.

The valley of the Bastan, in which Barèges is situated, is an excellent example of a valley half filled with morainic material, which is now deeply trenched and for the most part removed by the present stream. Patches of the moraine still remain adhering to the sides of the valley high above the present stream level. Great spaces swept bare by avalanches, here so destructive, can be seen at intervals, and high up on the steep slopes the terraces built by the French forestry department and by them planted with trees to prevent the snow from moving on certain of the more dangerous of the upper slopes, and in this way to avoid a repetition of the disastrous avalanches of former years.

At Barèges the excursion was brought to a close. The majority of those taking part in it, having on the following morning inspected the mineral springs for which the locality is renowned, left for Paris on the afternoon of August 15th, while a few members extended it by still another day and made a visit to the Cirque of Gavarnie, at the head of the Gave de Pau on the Spanish boundary, which is certainly one of the grandest spectacles in Europe, suggesting somewhat the great cliffs of the Yosemite valley (see Fig. 4).

The excursion was planned with the greatest care, and all the arrangements were personally supervised by Professor Lacroix, to whom the sincere thanks of the excursionists are due. Sleeping, as the party was obliged to do almost every night, in some remote mountain village, which was usually taxed to its utmost capacity to accommodate such an unusual influx of visitors, it was very difficult to make satisfactory arrangements in every case. Whatever comfort was to be had, however, the party enjoyed, and the excellent weather contributed greatly to the success of the excursion.

In entering upon a critical discussion of the phenomena observed, the writer feels that great care must be exercised in forming a judgment from what was of necessity a rapid and more or less incomplete study of the several occurrences. The members of the excursion were, moreover, at a serious disadvantage in not having any geological map of the districts visited. It was never possible to ascertain, except in a most general way, the areal distribution of any rock, the extent of any intrusion, or the distance to which any metamorphic changes could be traced. In preparing these notes, however, the information obtained in the field has been extended by a careful study of Professor Lacroix's published works, so far as they bear upon the localities in question, and a considerable number of thin sections of the rocks collected from the various occurrences, have also been examined.

In those cases where the granites of the Pyrenees were seen in contact with limestones, as, for instance, in the occurrences about Lac L'Estagnet, Pic du Camp Ras and Cirque d'Arbisson, the limestones near the contact were observed to contain various silicates which had crystallized out in them, as described above. Lacroix considers that in these cases, original differences in the composition of the beds influenced the nature of the minerals developed by metamorphism, but that the material for their growth was largely supplied by emanation from the intrusion. He believes that in the case of bands which were originally pure limestones, the minerals produced are garnet, epidote, zoisite, pyroxenes, amphiboles, quartz, feldspars and axinite. Where the original beds were impure, through the presence of siliceous or argillaceous materials, they are transformed into epidosites, garnet rocks, or feldspathic hornstones. Such limestones with silicates scattered through them, are not, of course, peculiar to the Pyrenees, they are seen in every Archean district in the world where limestones are found. The question always presents itself, as to how far these silicates represent original impurities in the limestone, and how far they are due to exhalations accompanying igneous intrusions. The limestones abutting directly against the igneous mass, even in the Pyrenees occurrences, are often free from these silicates In these contacts, however, the appearances go to show that the limestones during their recrystallization to marble have had added to them, in certain cases at least, as Lacroix holds, a certain amount of new material, probably from the waters and exhalations accompanying the intrusion; but this infusion of new material seems to be confined to a narrow zone about the contact, and is not by any means a regional phenomenon. In fact, in the occurrences at the Cirque d'Arbisson, some of the limestones of the Cirque itself, while greatly contorted, are practically unaltered in character, still retaining their original blue color and fine texture, and are free from all foreign minerals. The occurrence of axinite about the contacts does not seem to call for any especial notice, seeing that boron exhalations, giving rise to tourmaline, have been recognized as of frequent occurrence in contact zones by all authorities, having been found by Rosenbusch, even in the Barr-Andlau contact zone, which is always cited as affording evidence of the strongest kind, of the absence of metasomatic changes in the rocks about granite intrusions.

As mentioned above, in the district visited on the first two days of the excursion, that is, in the district about Lac l'Estagnet and the Cirque Camp Ras, there is between the altered limestone and the granite a zone, varying greatly in width but usually quite narrow, of what Lacroix terms "Roche Dioritique," and which is considered by him to have been formed by the solution of a portion of the limestone in the granite magma. This rock is said by Lacroix to occur only where the intrusion has limestone as a wall rock. It is a rock generally grayish in color and more basic in appearance than the granite, but of about the same size of grain, varying, however, considerably in grain and character from place to place. Lacroix states that a detailed study of it shows that it is not uniform in composition, but that it varies in minerological composition from a hornblende granite to a basic olivine norite, or even a peridotite. It completely surrounds detached masses of limestone, and has distinctly the appearance in the field of having been produced, as Lacroix believes, by a solution of the limestone along the margin of the granite. The conditions here are especially favorable for such a process of solution, as the limestone is broken up into a number of disconnected masses, thus exposing a large surface to the action of the granite.

No investigations into the chemical relations of the "Roche Dioritique" have been made, or at least none have been published; its exact chemical composition is unknown. This, however, is a subject on which information is especially required. It is most important to know in how far the composition of the "Roche Dioritique" approaches that of the normal granite of the district, with the addition of varying amounts of lime. It would seem that processes of differentiation must in any case have been at work in the mass after the solution had taken place, for it seems difficult to understand how any addition of lime to a granite magma can produce a peridotite. The only alternative, if this view of the origin of the mass is to be sustained, is to suppose that the exhalations given off by the magma first impregnated the invaded limestone in some places with minerals rich in iron, elsewhere with those rich in magnesia, and having thus produced out of the limestone a series of rocks of very diverse composition, the magma bodily dissolved them and thus obtained that irregularity in composition which caused it to crystallize out as rocks of such diverse composition as the mass cooled down.

The appearance in the field, however, in the opinion of the present writer, supports Lacroix's contention that this narrow band of "Roche Dioritique" was produced by the solution of the limestone in the granite magma about the contact. Detailed chemical studies and an accurate map of the area are, however, required before this contention can be proved, and it seems premature to say, as Lacroix does, "L'évidence de la transformation du granite par dissolution du calcaire est complète."[1] The development of this dioritic contact facies seems, even in the Pyrenees, to be unusual, and its volume as compared with that of the granite is insignificant, so that while, even if it be established that dioritic rocks may be produced by the solution of limestone in granite, it would scarcely indicate this as a probable origin for the great intrusions of these rocks met with in various other places.

---

[1] Le granite des Pyrénées et ses Phénomènes de Contact. Bull des Services de la Carte Geol. de la France; No. 64, p. 60.

The other class of granite contacts to be considered are those in which the granite comes against slates, shales, and similar argillaceous strata. In the "Livret Guide" prepared for those taking part in the excursion, Lacroix states that there exist in the Pyrenees, notably in the Haute-Garonne and Hautes-Pyrénées, many granite contacts of the ordinary type, long since described, which present the regular and usual succession of spotted slates, spotted or nodular micaceous schists, and andalusite hornstones; but that the contact zones of the Haute-Ariège, visited on the excursion, were chosen because they present striking examples of a much more intense alteration, in character analogous to certain other French occurrences described by Michel-Lévy, which are characterized by a marked "feldspathisation" of the invaded rocks, indicating the "importance prépondérante" of deep-seated emanations in the case of igneous contacts, and affording evidence of a wholesale incorporation of the invaded rock.

"Au contact immédiat du granite, en effet, s'observe une zone constante dans laquelle les schistes et aussi les quartzites se chargent de feldspaths, soit par imbibition, ces minéraux jouant le même rôle que le quartz dans les schistes micacés, soit par injection en nature du granite lui-même. Il est possible de suivre, pas à pas, tous les stades de feldspathisation et les passages insensibles entre ces schistes feldspathisés (Leptynolites) et le granite lui-même." In certain cases, as in the valley of the Baxouillade (near the Cirque de Ras), he goes on to say, these two types of "feldspathisation" are superimposed in one and the same rock, giving the invaded rock a gneissic facies, which in certain cases is so pronounced that it resembles a veritable gneiss.

This process of "feldspathisation" may thus, according to Lacroix, take place in two ways, (1) by imbibition, and (2) by the injection of little veins of granite all through the invaded rock.

In the first case the shales next to the granite, in what is commonly called the hornstone zone, which contain, as in all contact zones, more or less biotite, have feldspar developed all through them by emanations accompanying the intrusion, being thus converted into micaceous feldspathic schists, called in France Leptynolites. The usual type of Leptynolite is stated to possess exactly the same structure as the non-feldspathic micaceous schists, but under the microscope it is seen to contain grains of feldspar (orthoclase or plagioclase), which, like the quartz grains in the rock, are allotriomorphic, their form being largely determined by the biotite. The proportion of the feldspar present is extremely variable; the mineral may be present merely as a few grains here and there in the rock, or the proportion may be greater—the feldspar in some cases being more abundant than the quartz—as in the case of some of the Leptynolite from near Baxouillade. When this is the case, and the rock becomes coarser in grain with an abundance of mica, it passes into a veritable gneiss.

In the second case the granite is injected at intervals in the form of little veins between the lamellæ of the schist, the veins when followed out to their feather edges fading away insensibly into the schist. This is known as "lit par lit" injection, and also gives rise to a gneiss.

The appearance of the contacts of this class visited on the excursion does not strike the observer as being at all unusual. The explanation which at once suggests itself is that the acid granitic magma which has, by virtue of its acidity, apparently eaten into and dissolved the limestone in certain places and to a limited extent, has not been able to produce any marked effect on the shale. It has forced its way into the shattered strata along the contact, in the usual manner, sending a swarm of little dykes or veins into it in places, and everywhere baking it into a more or less micaceous hornstone-like mass. Fragments of the altered shale, abundant near the contact, less so at some distance, lie scattered about in the granite. These often retain their angular character, but at other times are seen to have been somewhat softened and pulled out into more or less elongated forms, appearing as dark streaks in the granite. The shale has been recrystallized, as in the case of every hornstone, the phenomenon being, of course, more pronounced in the separated fragments which are completely enveloped in the granite magma. The "lit-par-lit" injection is a not unusual phenomenon of contact in all igneous intrusions, and merely produces a mechanical admixture of granite with shale along the immediate contact of the intrusion without in any way necessarily altering the composition of either rock, or producing anything which is not manifestly a mixture of two distinct rocks. The appearance of feldspar in the altered shale—its "feldspathisation par imbibition"—does not necessarily indicate any addition of material. If there were not alkalies in the shale, the appearance of feldspar in the altered rock would be an evidence of the addition of these elements. But, as the analysis of shales from all parts of the world show, alkalies are almost invariably present, amounting on an average to about 4.75 per cent. This would, in the case of a thoroughly recrystallized rock, afford the material for as much as 25 or 30 per cent. of feldspar, and it would seem that there is seldom more, or in fact as much as this, present in the Leptynolite.

Gneissic rocks of a peculiar type found continually associated with the Laurentian limestones of Canada, and which have precisely the character of the more altered forms of these Leptynolites, when analyzed have been found, in many cases, notwithstanding their content in feldspar, to have a chemical composition identical with that of ordinary roofing slate, being in fact nothing more than shales which are completely recrystallized. On the other hand, thin sections of the most altered leptynolite from Pont de Kerkabanac contain more feldspar than would be expected in an altered shale.

While, then, it is impossible to assert that there has been no addition of material to the altered shale, no evidence seems to have been brought forward that there has been such addition, or that these occurrences differ from the ordinary type of contact

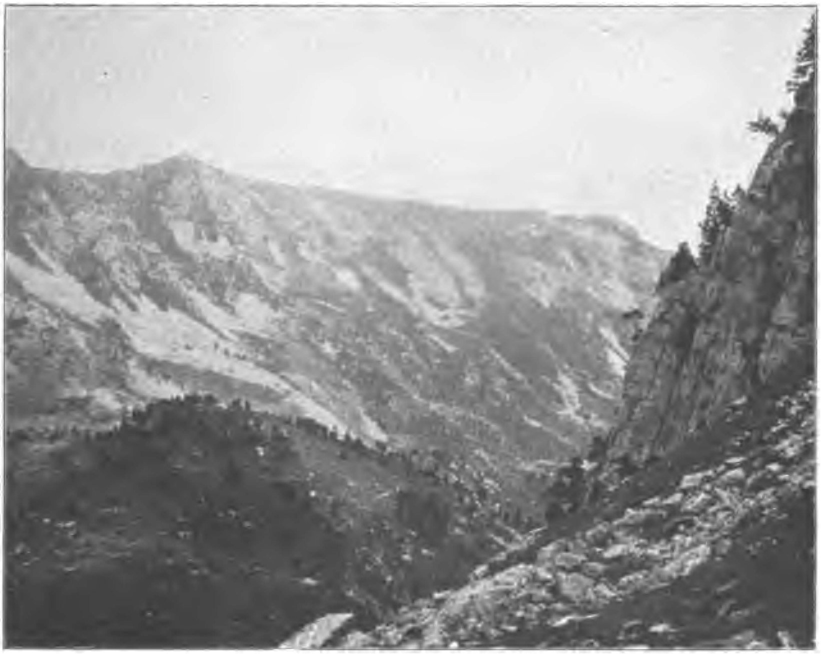


FIG. 1.

Near L'Etang de l'Estagnet.

Ridge of granite in distance. On right, cliff of thinly banded limestone, much altered and filled with garnets.

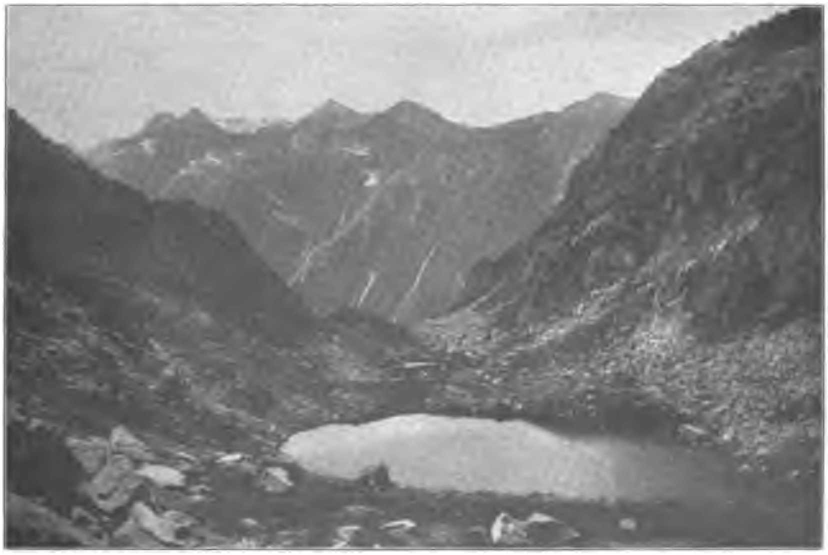


FIG. 2.

L'Etang de Baxouillade.

In foreground, granite with inclusions of schist and "Roche Dioritique." The mountains in the distance are composed of granite with pre-Cambrian limestone and "Roche Dioritique." The depression in the center of the range is formed by a Permo-Carboniferous limestone, which is altered by the granite.

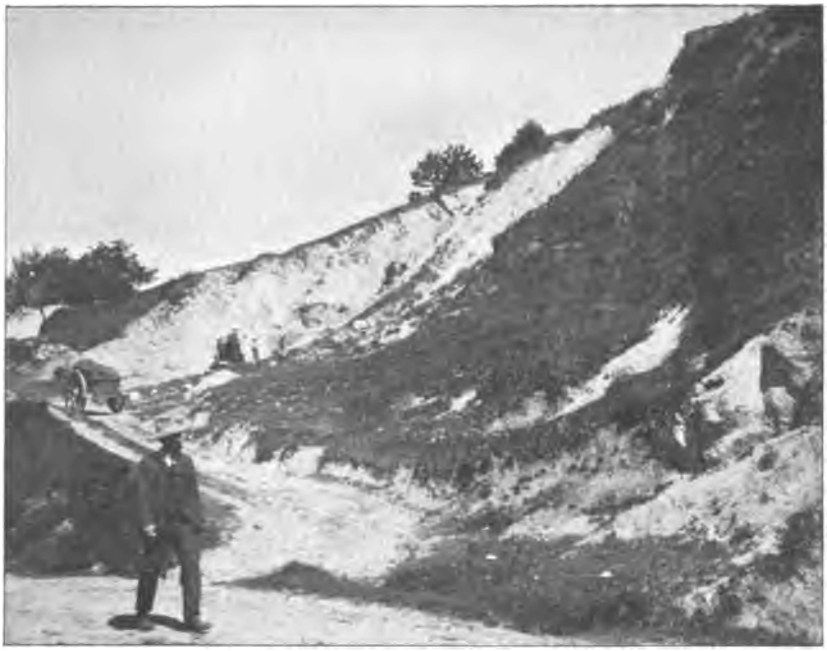


FIG. 3.
Quarry in Nepheline Syenite—Poussac.

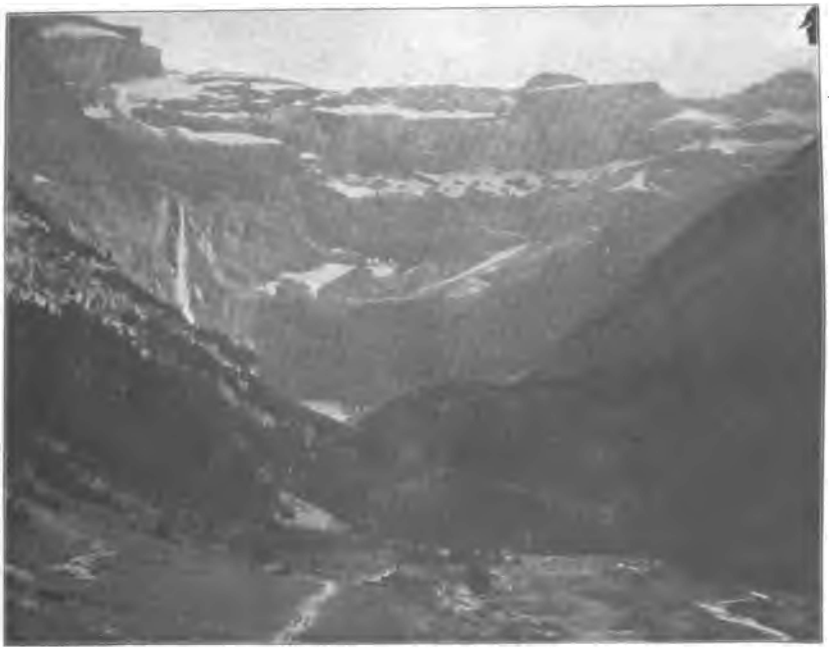


FIG. 4.
Cirque de Gavarnie.

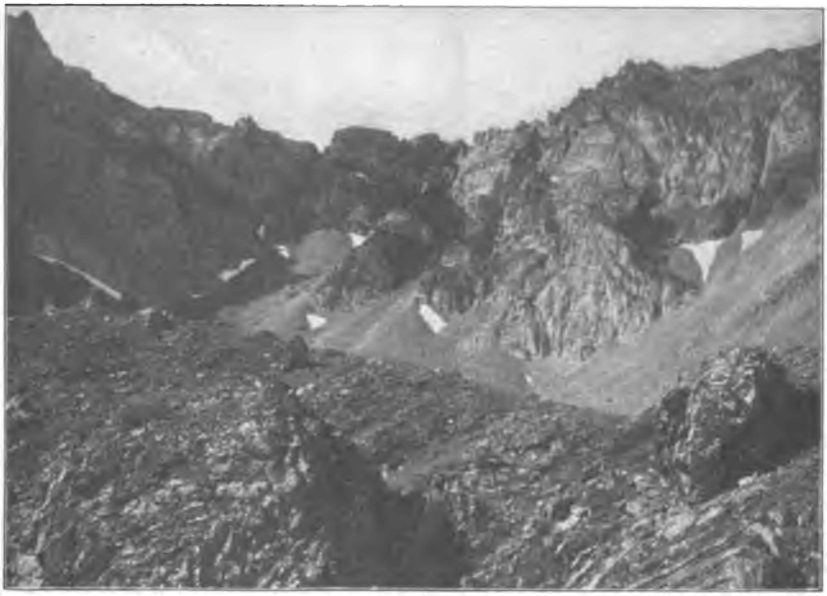


Fig. 5.
Cirque d'Arbisson.

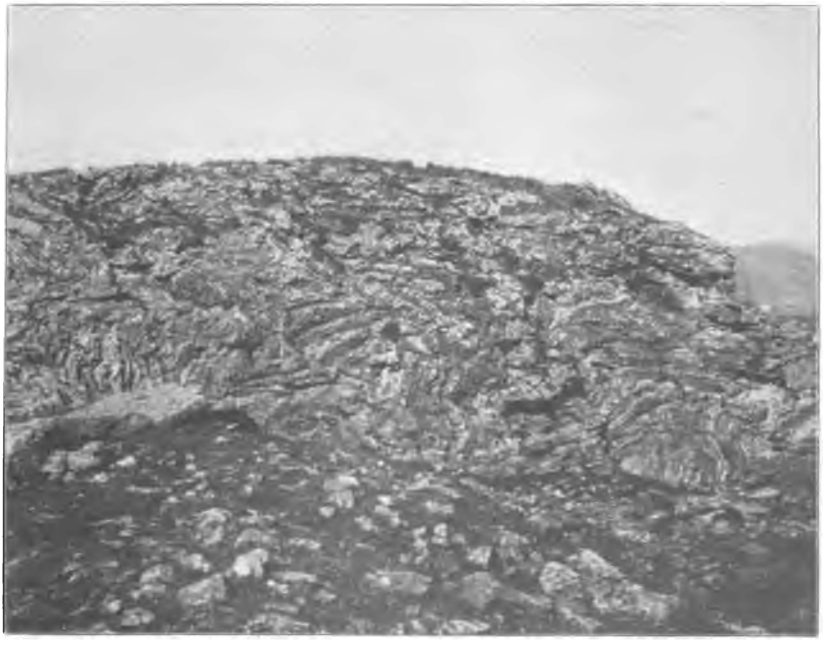


Fig. 6.
Contorted Strata at the Cirque d'Arbisson.

zones. What is required to establish this, is an exhaustive series of chemical analyses of carefully selected material, showing the composition of certain definite beds in their original and altered forms. Such an investigation would be of the greatest interest and highest importance to geological science at the present time.

Although, therefore, it is possible that some of the Archean gneisses which now have no longer the composition of any ordinary sediment, may represent shales which have been transfused with new material by emanations accompanying granitic intrusions, the studies hitherto made of these Pyreneean contacts do not, in the opinion of the writer, afford any conclusive evidence that such emanations have this transforming power. Still further are they from establishing the contention that granitic intrusions are merely great areas of shale or other sedimentary rocks changed in situ into granite, which is the view of their origin held by Michel-Lévy and Lacroix. "Je considère donc toutes ces couches métamorphiques isolées aujourd'hui au millieu du granite comme le résidue non digéré des assises sédimentaires dont le granite á pris la place."[1] "La mise en place du granite s'est effectuée par dissolution graduelle des roches sédimentaires dont il occupe la place."[2] This conclusion would, of course, if established, be of the greatest interest, but the evidence hitherto put forward seems quite insufficient for that purpose.

The metamorphism of the sedimentary strata in the vicinity of the intrusions of the basic rocks (ophite and lherzolite) is also attributed by Lacroix largely to the action of emanations from deep-seated sources. "L'impuissance de la lherzolite à opérer des transformations métamorphiques par l'action de sa propre substance est démontrée par l'absence de zones de passage entre elle et les sédiments métamorphiques et par la nature des minéraux produits à son contact. . . . . La roche modifiée a fourni une partie des éléments nécessaires à la formation des mineraux néogènes, mais beaucoup de ces éléments ont été nécessairement apportés des profondeurs, sous forme d'émanations, ayant une composition chimique différent de celle qu'à priori on pouvait supposer, étant connue la composition de la lherzolite."[1] There is, however, here again the same absence of the chemical evidence which would serve to definitely establish this conclusion.

---

[1] LACROIX: Livret, Guide, p. 15.

[2] LACROIX, Le granit des Pyrenées, etc., p. 3.

It is also to be noted that in the Pyrenees, dynamic action has followed the development of the contact zones above described. Lacroix observes that the minerals produced by the contact metamorphism are often much deformed by subsequent movements, but adds: "J'ai pu constater avec précision que les phénomènes de contact jouent un rôle prépondérant dans la production des nombreuses roches métamorphiques que l'on rencontre dans toute l'étendue de la chaîne."[2] As, however, it is a matter of extreme difficulty, if not an impossibility, in all cases to determine to which class of metamorphic agencies certain rocks are due, the question as to how far dynamic action may have at least contributed to some of the changes attributed to contact action is one which cannot be considered as entirely settled.

To sum up therefore it may be said, that while the transfusion of a certain amount of material into the limestones along the immediate contact of the intrusions and also a solution of the limestone to a limited extent in certain cases seems highly probable; the wholesale transformation of limestone into diorite, or of shale into gneiss and granite, which has been described in the case of these contact zones of the Pyrenees, is as yet very far, indeed, from being proved.

FRANK DAWSON ADAMS.

GEOLOGICAL DEPARTMENT
McGILL UNIVERSITY.

---

[1] LIVRET, Guide, p. 5.

[2] Les Phénomènes de contact de la Lherzolite et de quelques Ophites des Pyrénées. Bull. des Sciences de la Carte Géol. de la France, No. 42, p. 133.

VALLEYS OF SOLUTION IN NORTHERN ARKANSAS

PROFESSOR G. F. MARBUT has called attention to valleys of solution in Missouri.[1] Before this had come to the present writer's notice, he had become convinced that a type of valley which occurs in large numbers in the Boone chert of Arkansas owes its existence to the differential solution of the rock.

The Boone chert lies at the base of the Mississippian series in Arkansas. Over a large part of the region north of the Boston Mountains, erosion has left this as the surface rock. It approximates 400 feet in thickness and is essentially an immense deposit of limestone containing chert which varies greatly in amount, both horizontally and vertically.[2]

In all places where the Boone chert is the surface rock, the calcareous portion has been partly removed by solution, leaving a residue of chert, in places several inches deep, on the surface. The universal distribution of the small chert particles over the surface reduces the run-off to the minimum and increases the underground water to the maximum. As a consequence, valleys of solution are numerous throughout the region in which this is the surface rock. So different are these valleys from those of corrasion that they attract the attention of even the untrained observer. While seldom of great length, their length is always great in proportion to the width, and the latter is strikingly uniform throughout. To borrow a term from biology, they are always bilaterally symmetrical, and their slopes are steep (Fig. 1). They are remarkably straight, seldom deviating from a straight line more than a few feet except at the points where two valleys unite (Fig. 2). Probably the most striking feature about them is that they head suddenly, the heads often having exactly the appearance of half a sink-hole cut with a vertical plane through the center. Not infrequently the heads are forked, as shown in Fig. 1. The bottoms and slopes are covered with angular residual chert, leaves and branches of trees (Fig. 1). If surface water ever flows through the upper parts of these valleys, it is only after excessive rainfalls. Extended travel over the region has not yet brought to the writer's notice a single case in which the upper part of one of these valleys has been occupied by surface water in sufficient quantity to remove the residual chert.

---

[1] Missouri Geological Survey, Vol. X, pp. 88–92.

[2] For a full description of the Boone chert, see Rep. of the Ark. Geol. Surv., 1890, Vol. IV., pp. 94–107.

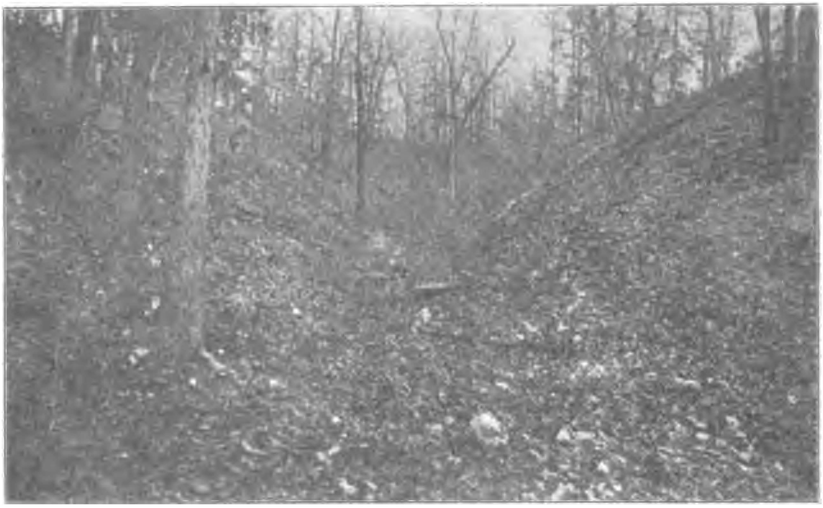


FIG. 1.

Unlike the valleys which Professor Marbut describes in Missouri, these valleys are narrow and steep-sloped in their upper parts and pass into rather wide, open valleys which owe their forms to both solution and corrasion. The topographic transition from that part of the valley that is due wholly to solution to the part that is due to both solution and corrasion is of course gradual. The point, as the writer conceives it, where the one passes into the other is determined by the groundwater level. Above the point where the valley cuts into the groundwater, the work is done by solution; below that point a surface stream exists which adds the work of corrasion to that of solution, the latter occurring mainly on the valley slopes above the stream bed. As this work goes on and the stream bed continues to be reduced more and more below the average level of groundwater, the stream grows in size, and in time, by meandering, is able to produce a wide valley.

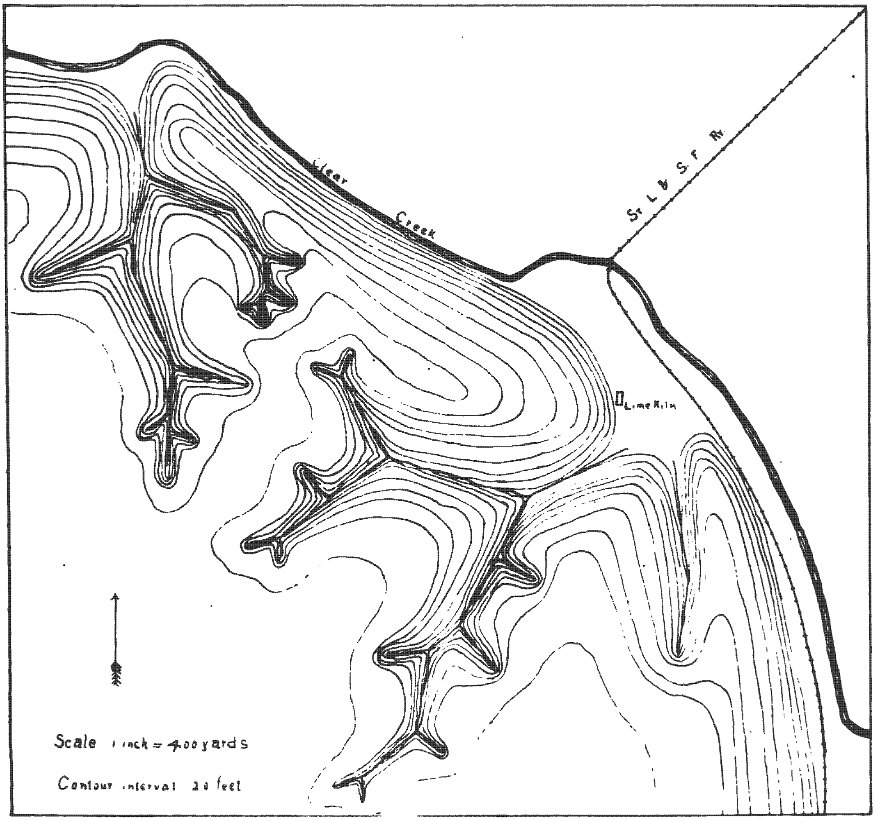


FIG. 2.

The point at which the valley cuts into groundwater of course varies with the seasons, but on the whole it is moving up the valley because of the differential solution brought about by the large amount of groundwater moving down the slope from either side and meeting beneath the bed of the valley.

Fig. 2 is a map of two of these valleys with their tributaries, four and a half miles north of Fayetteville. The map was made with a plane-table without correction for magnetic variation. These are typical of valleys that occur in the Boone chert of Arkansas by the thousand. The heavy lines are placed along the bottoms of the valleys only to bring to notice the angles at which they join each other. These angles vary from 60 to 100 degrees or more, the most common one being 80 degrees. It will be noticed that the angles at which the main valleys and their tributaries unite are quite different from those of corrasion.

The writer thinks there can be no doubt but these valleys are determined by the jointing of the horizontal beds of rocks. The double heads which are so common among them are tributary valleys in their incipiency, following joints which intersect along the course of the main valley.

The large valleys which contain the master streams of the Boone chert region were probably inherited, with their streams, from the former superimposed rocks, but the valleys here mentioned owe their origin and development to solution, aided possibly by the removal of part of the residual chert after the most excessive rains. A. H. PURDUE.

UNIVERSITY OF ARKANSAS,
Fayetteville, Arkansas.

STUDIES FOR STUDENTS

THE STRUCTURE OF METEORITES. I.

THOSE portions of cosmic matter which from time to time fall to the earth and which are known under the general name of meteorites, have now for about a century been objects of collection and study. Earlier studies of this matter were, on account of its limited quantity and variety, necessarily confined chiefly to the description of individual masses. Comparative study, has, therefore, been carried on to only a small extent and the possible knowledge to be gained by investigation along this line is as yet far from complete. The number of localities from which meteorites are now known may be stated in round numbers as 550 and the total weight of cosmic matter now preserved and in one way or another available for study, as about 161 tons (146,716 kilograms).

Lines of investigation.—The lines along which the study of meteorites has been and is being conducted can be classified as follows, each, of course, being more or less intimately related to or inclusive of the other: (*a*) chemical, (*b*) mineralogical, (*c*) petrological, (*d*) physical, and (*e*) structural. Each of these may be (1) analytical, and (2) synthetical, and may include (3) the study of terrestrial analogies. Of the above courses of investigation the first three have been the lines along which study has been most extensively conducted hitherto. Summarizing briefly their results, it may be stated that the chemical investigation of meteorites has resulted in the identification of twenty-five elements, all similar to those known upon the earth; the mineralogical in the determination of at least twenty mineral species, some of which are similar and others dissimilar to terrestrial compounds, and the petrological in the classification and tabulation of the characters which meteorites display as mineral aggregates.

The physical investigation of meteorites has been confined chiefly to studies of their spectra and comparisons of these with the spectra of comets, nebulæ, and other heavenly bodies. Studies of thermo-luminescence, magnetism and polarity as exhibited by meteorites have also been made. With the results of the structural studies of meteorites it is the purpose of the present paper to deal in some detail.

Structure · a feature distinguishing meteorites from terrestrial rocks.—It is from the point of view of structure that meteorites differ most completely from terrestrial rocks. In chemical, mineralogical, petrological and physical characters some meteorites closely resemble terrestrial rocks. The meteorite of Juvinas, for instance, so far as the above characters are concerned, is similar to a basalt, while many of the iron meteorites find a perfect analogue in the terrestrial irons of Greenland. When the structure of meteorites is considered, however, a distinction is apparent. No resemblance to the clastic texture of the Juvinas meteorite is to be found among terrestrial basalts, nor does the terrestrial nickel-iron show satisfactorily the Widmanstätten figures so characteristic of the iron meteorites.

It is along this line of study that the geologist finds problems which his science is especially adapted to solve, for the problems afforded are similar in many respects to those included under the group of structural and dynamical, or, as it is sometimes termed, phenomenal geology. Just as studies of the latter sort avail to give a knowledge of the forces and conditions under which different rock structures and rock movements are produced, so studies of the structure of meteorites may be expected to discover the conditions under which cosmic matter is formed and the forces to whose action it is subject in space. Since, further, this cosmic matter reaching us as meteorites has striking and important analogies with that, not alone of the crust of the earth, but it may be believed also of its entire substance, the fascinating possibility is presented of reading in the mass of meteorites many chapters in the history of the earth which would otherwise be locked up within its interior.

Matter of meteorites of two kinds.— Matter constituting meteorites may be described as of two kinds, metallic and stony. The metallic matter is chiefly an alloy of iron and nickel, the stony matter chiefly the silicates chrysolite, pyroxene, and feldspar. Single meteoric masses may consist of but one of these kinds of matter or may be made up of a union of the two.

Three groups of meteorites according to their components.— According to the relative quantities of each of the two above mentioned kinds of matter it is convenient to divide all meteorites into three great groups. Those made up wholly or largely of metal (*aerosiderites*, *holosiderites*) form the first group. Those made up of about equal quantities of metal and stone (*aerosiderolites*, *lithosiderites*, *syssiderites*) form the second group. Those made up wholly or largely of stone (*aerolites*, *sporadosiderites*) form the third group. No sharp dividing line can be drawn between these groups. They pass into one another by every gradation, and meteorites of the two kinds even occur in the same fall. Yet meteorites of these groups differ in many essential characters and their separation becomes a matter of great convenience in study. For purposes of the present study the three classes will be sufficiently designated by the terms iron meteorites, iron-stone meteorites, and stone meteorites.

Two groups of meteorites according to their origin. — With respect to their origin meteorites may be either (1) monogenic (of single origin) or (2) polygenic (of various origin). Most of the iron meteorites are plainly monogenic. Many show such homogeneity and uniformity of structure as could belong only to a single crystal. Thus the iron meteorite of La Caille, a mass of 591 kilos in weight, contains inclusions of troilite arranged in parallel rows throughout in such a manner as to indicate a uniform and continuous crystallization of the entire mass. Likewise from a mass of a Toluca meteorite a cube may be cut which shows on etching a perfectly regular octahedral structure throughout. The same parallelism of planes may be traced on an etched section of almost any of the so-called cubic meteorites, such as Coahuila, Hex River, etc. A few iron meteorites are however plainly polygenic. An etched section of the Mt. Joy meteorite for example shows the mass plainly to be made up of irregular iron fragments. The structure of each fragment as shown by its etching figures is *sui generis*, and indicates an independent origin. The iron of Zacatecas is likewise made up of individual grains the size of a hazelnut to that of a walnut. These are separated by areas of troilite.

Many of the iron-stone and stone meteorites are monogenic but more are made up of two or more different kinds of rock. To draw the dividing line between the monogenic and polygenic meteorites of the last two classes is not an easy task and the opinion of no two observers would probably be the same in regard to it. The meteorite of Stannern for instance was described by one observer as crystalline and by another as clastic. Tschermak, who has given the matter profound study, is disposed to regard practically all stone meteorites as of a tuffaceous or clastic character while Wadsworth after examining many meteorites concluded that none which he had examined could be considered "fragmental in the sense of consolidated cold masses joined together." The present writer can only state that in his opinion some stone meteorites are so uniform in character that crystallization from a single magma is indicated while on the other hand many meteorites have a clearly brecciated and tuffaceous character showing them to be polygenic.

Structures of terrestrial origin to be eliminated.—In all study of the structure of meteorites with a view to learning their preterrestrial history, care should be taken to eliminate all phenomena of terrestrial origin. Thus the crust of meteorites and their surface markings are usually considered, and without doubt properly, to be produced during the passage of the mass through the earth's atmosphere. The possible effects on the interior of a meteoric mass, of heat developed by such passage should also be borne in mind in study. Again the force of impact with which a meteorite strikes the earth is often very great. It should be considered whether such a blow might not give rise to phenomena of internal movement within the mass. Again processes of corrosion and decomposition go on if the meteorite is exposed on the earth's surface for any length of time, which may have their effect on the structure of the meteorite. These therefore must be judged and eliminated. Again, the fissures found in meteorites are believed by many to be the result of cracking from the sudden development of heat caused by the entry of the mass into the earth's atmosphere and the veins of meteorites are by some thought to be fissures filled by matter fused by such heating. Due weight must be given these possible effects and all that are certainly of terrestrial origin must be left out of consideration.

Uniformity of mass structure of single meteorites.—The iron meteorites usually show remarkable uniformity of structure throughout. Sections from different portions of a single mass or even different masses of the same fall usually give on etching, figures so similar that the meteorite to which they belonged can be recognized at a glance, even if the specimens have been widely separated. In some, however, there are variations in the same mass. Thus the Floyd county iron according to Kunz and Weinschenk while possessing a generally cubic structure shows portions which are granular; the Linnville iron according to Kunz is partly of cubic structure and partly amorphous. The Carlton iron is partly rich in plessite and partly poor in plessite. The Holland Store iron has portions coarse-grained and fine grained. Four of the five masses found near Staunton, Virginia, are quite similar in structure, showing on etching, figures made up of short, swollen bands. The etching figures of the fifth mass are, however, made up of long, straight bands. Moreover the taenite of the first four is brittle, of the fifth elastic. So sharply does the latter mass differ from the others that Brezina regards it as belonging to a different fall, but it is more likely that the differences are those of structure. Such exceptions are however so rare as to emphasize the fact that on the whole iron meteorites are uniform in structure. Speaking in a general way the iron-stone and stone meteorites are likewise uniform in mass characters although such as are clastic or brecciated have the variations which might be expected from the accidents of aggregation. The monogenic meteorites may show variations from fine grain to coarse grain and vice versa and some portions may contain more stone or metal than others, but the general structure may be said to be uniform.

Similarities of structure in meteorites of different falls.—While the individuals of a single fall are usually similar in structure and composition those of different falls often differ so that they may be easily distinguished. In comparing the meteorites of a large number of falls, however, similarities are readily seen which permit the grouping of several falls together as being of practically identical matter. A number of classifications of this sort have been made of which those of Brezina and Meunier are the latest and most complete. Brezina, who makes structure the leading feature of his classification, has thus reduced all known meteorites to sixty-one groups, while Meunier, with whom mineralogical composition is the chief criterion, makes sixty-two groups.

Degrees of coherence.—The iron meteorites are, as might be expected, usually strongly coherent and tenacious to a high degree of malleability. Yet there are variations in this respect. The iron meteorites showing coarse etching figures can usually be sawed only slowly and with great difficulty, while those of an amorphous or finely crystalline character cut more readily. Some iron meteorites, such as those of Coahuila and Nelson county, can be broken readily by the blow of a hammer. Among the stony meteorites all stages of consolidation may be traced from those of an almost flint-like toughness (Long Island) to those so friable as to crumble on handling (Warrenton). The majority of stony meteorites are fairly coherent so as to take a good polish.

Kinds of structure according to texture.— According to what is often known as rock texture, meteorites display a number of variations which are for the most part entirely comparable with similar variations seen in terrestrial rocks and may be described by the same terms. Accordingly, among the monogenic meteorites crystalline, cryptocrystalline and vitreous or amorphous structures may be noted. Among the polygenic meteorites, brecciated, agglomerated, psammitic or sandstone-like and tuffaceous structures may be noted. Stratified, foliated, and fibrous structures are entirely lacking. Both among monogenic and polygenic meteorites occurs a kind of structure resulting from the mass being made up largely of little spheres called chondri. The structure of such meteorites is not strictly comparable to that found in any terrestrial rocks. Meunier describes it by the term oölitic, but the analogy is not a very close one. The structure, therefore, requires a distinctive term, chondritic, meaning a rock made up wholly or largely of chondri.

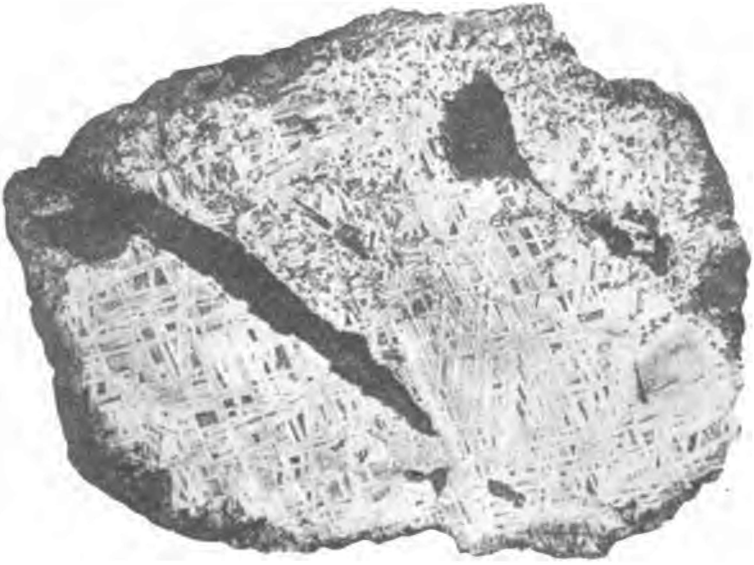


FIG. 1.—Widmanstätten figures. Meteorite from Toluco, Mexico.

CRYSTALLINE STRUCTURE.

Iron meteorites.—Sections of most iron meteorites when heated or etched by acids or other etching agent display upon their surface well-marked figures formed of series of parallel bands intersecting in two or more directions. These figures are called, after Alois von Widmanstätten, who first produced them in the year 1808 by heating a section of the Agram meteorite, Widmanstätten figures. The production of these figures is evidence that the meteorites on which they occur (1) have a well-defined crystalline structure and (2) are not homogeneous in composition. Evidence of crystalline structure is not confined to results obtained by etching: many meteorites show in their natural condition a structure of plates intersecting at definite angles. Study of the angles at which the bands meet both in etched and natural specimens shows that the crystallization of most iron meteorites is octahedral, *i. e.*, they are formed of plates or lamellæ arranged parallel to the four pairs of faces of the octahedron. Though this arrangement may for practical purposes be considered a simple one, it is really according to Linck the result of a polysynthetic twinning. The angles at which the bands intersect in any given section depend wholly on the direction of the section, as the accompanying figures will show. If the section is parallel to an octahedral face it will show three systems of bands intersecting at angles of 60° (Fig. 2). If the section is parallel to the face of a cube there will be two systems of bands intersecting at angles of 90° (Fig. 3). If the section is parallel

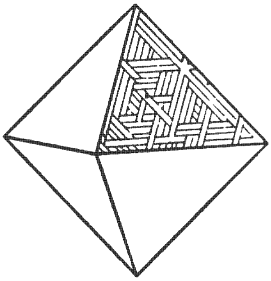


FIG. 2.

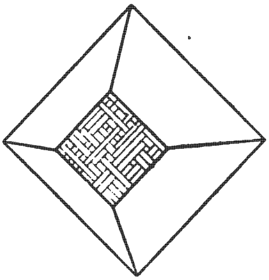


FIG. 3.

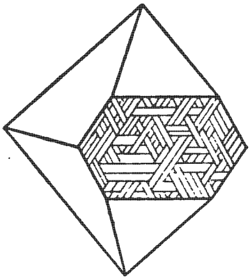


FIG. 4

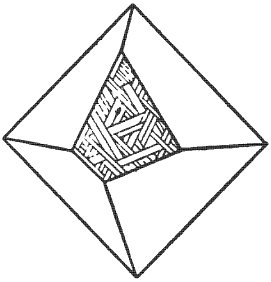


FIG. 5.

to a dodecahedral face there will be two systems of bands intersecting at angles of 109° 28′ and two others parallel to each other which will bisect this angle (Fig. 4). Sections in any other direction (obviously by far the most common) will produce bands running in four directions and intersecting at unequal angles (Fig. 5). A small number of iron meteorites show a cubic rather than an octahedral crystallization, *i. e.*, they are formed of plates arranged parallel to the faces of a cube. These are known as "cubic irons," or hexahedrites. A still smaller number exhibit no crystalline structure nor Widmanstätten figures. These are known as amorphous irons or ataxites. The relative numbers of these kinds of irons given in Brezina's classification are, of the octahedral irons, 125; of the cubic irons, 26; and of the ataxites, 14. Among the octahedral irons the particular figures exhibited will vary slightly with almost every fall, on account of varying width, length, shape and arrangement of the bands and abundance and forms of included matter. Width of bands is made by Brezina the basis of classification of the octahedral irons. He describes the widths as varying from more than 2.5^{mm} to less than 0.1^{mm}. When the intimate structure of the bands themselves is considered, they will be found to consist of a broad band of dull luster and iron gray color depressed below the surface when etched or covered with a thick layer of oxide when heated, bounded on either side by thin lamellæ of bright luster and silver white to yellow color, which stand out in relief or are little oxidized. To the broadly banded alloy, Reichenbach, who first investigated this structure, gave the name of Balkeneisen or *kamacite*, from *κάμαξ*, a pole or shaft. To the narrow banded alloy he gave the name of Bandeisen or *taenite*, from *ταινία*, a fillet or ribbon. When angular interstices occur between the intersecting bands they are often filled with an alloy intermediate in properties between kamacite and taenite. To this Reichenbach gave the name of Fulleisen or *plessite*. The three alloys together he called "the triad." Chemical analysis of the members of the triad shows them to be alloys of nickel and iron, the first two of which have a fairly uniform chemical composition, though not sufficiently constant to warrant their being considered distinct mineral species. The percentage of nickel is lowest in kamacite, thus accounting for its greater solubility in acid. The formula Fe_{14} Ni expresses the usual proportion of iron and nickel which it contains. Taenite contains a much larger proportion of nickel and hence is less soluble in acid. Its formula has been given both as Fe_6Ni and Fe_5Ni_2. According to Tschermak the taenite of the Ilimäe meteorite consists of a network of different substances, and it is doubtful whether in any meteorite it is a homogeneous substance. The third member of the triad, plessite, has a very variable composition and the latest investigations make it doubtful whether it differs essentially from kamacite. Inclusions of other minerals occurring in iron meteorites are usually surrounded by a layer of kamacite. Kamacite of this sort, while it does not differ in composition or structure from the ordinary kamacite, has been designated by Brezina as "*wickel-kamazit*" (swathing kamacite) and was called by Reichenbach "Hulleisen." While the octahedral irons always contain two or more of the above alloys, cubic irons contain only one, viz., kamacite. This usually shows a parallel banded structure on etching, but is not divided into well-marked lamellæ. Etched sections of cubic irons also exhibit fine depressed lines called Neumann lines. They are somewhat promiscuously scattered, having neither the abundance nor the regularity of Widmanstätten figures. They are usually interpreted as intercalated lamellæ in twinning relation to the main individual which are more easily dissolved by acid than the other lamellæ. They have been likened to the twinning lamellæ parallel to $-\frac{1}{2}R$ often seen on a piece of calcite. Tschermak regards their formation as simultaneous with the crystallization of the iron, while Sadebeck and Linck consider them of secondary origin, perhaps as a result of jar or shock. Many cubic irons also exhibit orientated sheen (***krystal damast, moiré metallique***). This is formed partly by differential etching of parallel bands and partly also by the above described Neumann lines. Sheen, Neumann lines, and parallel banded structure of the cubic meteorites will be found on close examination to characterize the kamacite of many octahedral irons (*schraffirten kamazit* of Reichenbach), while the kamacite of other octahedral irons is wholly granular (*fleckig kamazit* of Brezina).

Regarding the part played by the different alloys in the process of crystallization, opinions differ, though the general opinion is that the kamacite crystallized first and the other substances arranged themselves accordingly. Sorby likened the process to the forming of needles of ice on the surface of water, leaving angular spaces which were filled later. J. Lawrence Smith on the other hand, thought that the foreign minerals, such as schreibersite, separated and crystallized first and the purer alloys followed. Huntington is of a similar opinion and draws attention to the close resemblance in appearance between Widmanstätten figures and the arrangement of inclusions of magnetite in mica in support of the view.

Most authorities agree that the crystalline structure exhibited indicates that the masses must have remained for a long time in a fused or viscous state from which they cooled but slowly. The conclusion of Tschermak was that "the greater number of meteoric irons exhibit a structure which indicates that each formed a part of a large mass possessing similar crystalline characters and the formation of such large masses presupposes long intervals of time for tranquil crystallization at a uniform temperature." Sorby reached a similar conclusion and regards the Widmanstätten figures "as the result of such a complete separation of the constituents and perfect crystallization as can occur only when the process takes place slowly and gradually. They appear to me to show that the mass was kept for a long time at a heat just below the point of fusion."

2. *Iron-stone meteorites.*—The metallic portions of most meteorites of this class show Widmanstätten figures on etching. The mineral silicates entering into the composition of the mass also often exhibit well-defined crystal forms, the perfection of which is

sufficient to permit accurate measurements of the crystal planes. A curious feature of these crystals, however, and one which has as yet received no adequate explanation is that they usually exhibit a rounding of the solid angles and edges, giving an appearance of a sphere on which facets have been cut.

3. *Stone meteorites.*—To what extent a primary crystalline structure characterizes stone meteorites, is a point regarding which, as has been said, no two observers are likely to agree. The minerals of many meteorites occur in well crystallized form, but whether they have crystallized *in situ* or are mere splinters from previously existing masses is a disputed point in most cases. The number of stone meteorites showing a holo-crystalline structure similar to that characterizing terrestrial rocks is certainly small. Such as may be of this character are fine-grained and resemble fine-grained basalts in their structure.

Among minerals occurring in well defined crystal forms, whatever their relation to the mass as a whole, enstatite, chrysolite, augite, and plagioclase are the most common and characteristic. The crystals of these minerals usually have well-defined boundaries and exhibit planes corresponding to those of terrestrial minerals of the same kinds. Twinned individuals are common and a lamellar arrangement of inclusions is sometimes seen. There is a complete absence, however, of layers of growth or of zonal structure so common in the minerals of volcanic terrestrial rocks. The crystal individuals often contain large quantities of glass and often present a highly fissile structure. Another remarkable feature is a complete absence of fluid inclusions. Gas pores while occasionally to be seen are exceedingly rare. The latter fact, it may be remarked, furnishes a strong argument against any theory which regards meteorites as having been formed directly from vapors.

CRYPTOCRYSTALLINE AND AMORPHOUS STRUCTURES

1. *Iron meteorites.*—The term amorphous irons or ataxites is usually used to designate iron meteorites which give no Widmanstätten figures on etching. Such irons are few in number and the

present supposed number will doubtless be further reduced by careful study since some accredited meteorites will be found to be artificial irons and others will give Widmanstätten figures on further treatment. The true ataxites resemble ordinary cast iron in structure. There are sometimes variations in a single mass from a compact homogeneous structure to one of a coarse grained character. Several show indistinct broad bands and others a sheen (*Eisenmohr*, *moiré metallique*) on etching. Inclusions of graphite, phosphides and sulphides of iron (such as schreibersite, troilite, etc.) occur as in the octahedral irons. Unusually high content of nickel characterizes some, while others have an average composition. On the whole the ataxites may be said to form an anomalous and little understood group.

2. *Stone meteorites.*—No stone meteorites are amorphous in structure as a whole; only the ground mass is sometimes found to be of this character. In some cases a ground mass appearing amorphous is found in reality to be made up of consolidated fragments of dust-like minuteness. In other cases, as in the stones of Richmond and Goalpara, the ground mass is really semi-glassy and unindividualized. The ground mass of most of the carbonaceous meteorites is of a black unindividualized character, and appears closely allied to the substance to be described later as forming veins. In the brecciated stones of Orvinio and Chantonnay a black ground mass cements the fragments of chondritic texture together and exhibits a distinct flow structure about them. A brown glass is also found cementing together some of the crystalline and tuffaceous meteorites.

BRECCIATED STRUCTURE.

This is of rather common occurrence. According to Wülfing's classification it characterizes meteorites of sixty-two falls. Breccias occur both of the type of angular fragments compressed together and of angular fragments imbedded in a ground mass which may have been at one time in a fused or pasty condition. Among the iron meteorites the fragments are largest in the Mt. Joy meteorite. The contour of each of these is so distinct that there can be little doubt that the mass was made up by the aggregation of solid angular fragments. The meteorites of Zacatecas and Kendall counties have a similar structure, though the component fragments are much smaller.

Some of the iron-stone meteorites have likewise a brecciated structure resulting from the imbedding of angular masses of silicates in a metallic base. The meteorite of Copiapo, for example, has such a structure and its formation is exactly analogous, in the view of Meunier, to the dike breccias produced on the earth by intrusive igneous eruptions tearing off fragments of the rock through which they have ascended and enclosing them in its pasty mass. In this case the intrusive matter was fused nickel-iron. In other iron-stone meteorites, such as Vaca Muerta and Eagle Station, the silicate fragments are likewise angular. Reichenbach is authority for the statement that the iron in these adapts itself to the form of the stone rather than the contrary.

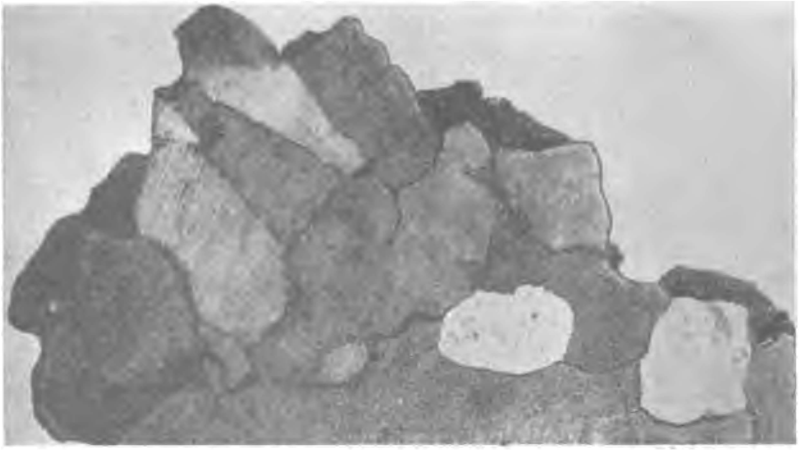


FIG. 6.—Brecciated structure. Mt. Joy Meteorite.

The fragments forming the breccia in stone meteorites are often of considerable size. The largest which I have noted in the stony meteorites (Weston) is about one cubic inch in contents.

Often the fragments differ enough in color from one another, or from the ground mass, so that the brecciated character is plainly visible to the naked eye. In the stone of Weston, for example, the ground mass is gray, the enclosed fragments blue. In the stone of Siena the angular fragments are of a dark color and the enclosing magma is light colored, while of Bandong, Saint-Mesmin and others the reverse is true. In other meteorites the two components differ chiefly in grain and coherence, as in the meteorites of Jelica, Manbhoom, and Soko-Banja. In these the ground mass is of a somewhat coarse, friable character, while the enclosed fragments are of a dark, fine-grained rock. In regard to the ground mass of other brecciated stone meteorites it may be stated that it may itself be made up of rock splinters, *i. e.*, have a tuffaceous character, or it may be crystalline or half glassy. The half glassy ground mass of the Orvinio and Chantonnay meteorites, as already noted, shows a distinct flow structure around the fragments which it encloses.

AGGLOMERATED, SANDSTONE-LIKE AND TUFFACEOUS STRUCTURES.

These may be said to differ from brecciated structure only in the smaller size of the component fragments. The fragments may range from the size of small peas in meteorites of agglomerated structure through that of coarse sand in those which are sandstone-like to that of splinters and fine dust in the tuffaceous meteorites. In the agglomerated meteorites it is often possible to recognize different kinds of rocks. Thus in the Parnallee meteorite Meunier believes he has recognized seven distinct lithologic types. Of the sandstone-like meteorites that of Chassigny is the best example. It is made up of rounded grains of the size of coarse sand. The Shergotty and Ibbenbühren meteorites are likewise granular in appearance. Not all observers, however, agree that the above are clastic in their origin. The tuffaceous structure is a common one in meteorites, Tschermak, as already noted, regarding practically all stony meteorites as of this nature. The resemblance of these to terrestrial volcanic tuffs is very close, though the stratification which usually characterizes the latter has never been observed. The tuffaceous meteorites are made up of splinters and dust varying in degree of consolidation. They are often finely porous so as to soak up fluids readily. The splinters of which they are made up may be similar in character (Shalka) or strikingly dissimilar (Luotolaks).

O. C. FARRINGTON.

(To be continued)

EDITORIAL

THE thirteenth meeting of the Geological Society of America, held in Albany, N. Y., was very satisfactory. The location was sufficiently central to insure a good attendance, the hotel accommodations were excellent and convenient to the place of meeting, and the number of papers was not more than could be read and discussed within the time of the meeting. The local committee, Dr. F. J. H. Merrill and Dr. J. M. Clarke, are to be congratulated on their hospitality and the success of their arrangements.

The postponement of President Dawson's address to the last day of the meeting was regretted by those who were unable to remain through the three days. It would seem advisable to have the presidential address delivered on the second day of the meeting, when there is the greatest number of members present.

The most notable feature of this meeting of the Geological Society, in the city that is looked upon as the cradle of American geology, was the conspicuous absence of a suitable monument to the memory of those pioneers of geological science who have opened a highway to stratigraphy through New York state, and have made of the state a corner stone of the geological structure of the whole country. Such a monument should take the form of a building in which not only the names and records of New York's venerated geologists may be inscribed and their collections preserved, but where their labors may be carried forward and from which inspiration and assistance may spread to geological workers throughout the state. In a state less than New York the absence of such a monument might pass unnoticed.

J. P. I.

THE second annual meeting of the Cordilleran section of the Geological Society of America was held on December 28 and 29. The morning session on the 28th took place in the council room of the California Academy of Sciences, in San Francisco. For the succeeding three sessions the members gathered in the rooms of the Geological Department of the University of California.

The following persons were present at the meeting of the section:

W. P. Blake, E. W. Claypole, A. S. Eakle, H. W. Fairbanks, E. W. Hilgard, W. C. Knight, A. C. Lawson, H. W. Turner, F. M. Anderson, W. C. Blasdale, F. C. Calkins, H. W. Furlong, O. H. Hershey, G. D. Louderback, C. F. Newcombe, W. J. Sinclair, J. C. Merriam.

At the first session Professor Wilbur C. Knight was elected chairman, Professor Andrew C. Lawson, secretary, and Dr. A. S. Eakle, councilor for the ensuing year.

In the course of the four sessions the following papers were read and discussed:

The Evidences of Shallow Seas in Paleozoic Time in Southern Arizona. By W. P. BLAKE, Tucson, Ariz.

In the mountain ranges of southern Arizona there is abundant evidence of shallow seas and shore lines in Paleozoic time. These shores were not, perhaps, a continental margin, but rather the borders of islands, crests of submerged mountain ranges rising at intervals above the Paleozoic ocean and with a trend or direction corresponding eventually to the direction of the mountain ranges of the region.

A cross-section of the territory northeasterly from the Gulf of California shows a succession of mountain ranges, some fifteen in number, in most of which ancient sandstones and conglomerates of Paleozoic age have been identified. Many of the exposures of quartzite are very thick, and these quartzites generally rest upon a coarse-grained porphyritic granite. Deep-sea deposits are not wanting. Thick beds of limestone, especially those of the Carboniferous, give evidence of depressed areas and of oscillations of level. So, also, the existence of thick, uplifted beds of graphitic coal in the Chiricahua Mountains bear testimony to the former existence of land areas, and show a far western extension of the vegetation of the Carboniferous.

Two localities of Devonian beds were described; one in the Santa Ritas and another at the northern end of the Santa Catalina Mountains.

The probable existence of Cambrian beds at several places was pointed out and the ancient tabular gneissic rocks of the Catalinas were referred to the Archean, and regarded as probable equivalents of the Huronian and Laurentian.

The Sierra Madre near Pasadena. By E. W. CLAYPOLE, Pasadena, Cal.

The paper opened with an expression of the surprise with which geologists who have worked principally in the East witness the enormous development and the excessive diastrophism exhibited by Tertiary and even by very late Tertiary strata in the West, and these characters are as well seen in California as in any other western state. The whole Tertiary period has apparently been signalized by thick accumulation, with alternate elevation and depression. Not less has its passage been characterized by volcanic outbursts of intense energy and by quiet outflows of lava almost unequaled in massiveness and extent.

Two great mountain ranges diverging in the north and meeting again in Kern county, inclose between them the San Joaquin Valley. This southern meeting forms one of the great natural features of the state—the Tehachapi Divide.

Speaking now only for the southern part of the state, there seems ample ground for the belief that these ranges have existed from at least Cretaceous if not from earlier Mesozoic time. It is not otherwise easy to find a source for the enormous Pliocene, Miocene and Eocene accumulations of the Pacific margin so far from the Sierra Nevada.

Thick gneissic strata of two types, and standing nearly vertical, compose the range of the Sierra Madre near Pasadena. That to the south contains a large proportion of hornblende, weathers rapidly and deeply, and is consequently eroded with comparative facility. That to the north is largely feldspathic, contains little hornblende, and of it consist the white crags that stand out so boldly on the upper slopes. The former of these masses cannot be less than 2000–3000 feet thick, but it does not rise in the mountain to a greater height than 3500 feet.

Of the wreckage from these two gneissic masses the material filling the valley of Pasadena is composed. From great bowlders near the foot of the Sierra it gradually diminishes till it becomes, in many places, a fine gravel and at last a fine silt. This last composes the adobe land around Los Angeles and also the many sheets of the same material which lie in the gravel, and are the holding-ground of the water supply. This has been so largely exploited during the two late dry seasons that the work has resulted in restoring confidence in the water resources of the valley, of which some had become rather doubtful.

The highly aluminous nature of many of these beds indicates a very extensive decay or kaolinization of the gneisses of the Sierra and together with the diluvial arrangement of the Pleistocene wash in the valley rather indicates a long continuance of the present climatic conditions than a past of greater and steadier rainfall.

The multiplication of wells has not yet shown any effect in lowering the water level unless perhaps in a few cases and this result is the more surprising and gratifying because it comes after two dry seasons in which only eleven inches of rain have fallen. Already this year, a greater total has been received than the above though the wet period has scarcely begun.

When to this is added the storage of the rainwater in tanks and ponds and the reforesting of the Sierras, wherever possible, it will be seen that the maintenance of the water supply in the future is encouraging.

Bates' Hole. By WILBUR C. KNIGHT, Laramie, Wyo.

Bates' Hole, a great natural depression, is located along the east and west boundary line between Carbon and Natrona counties, Wyoming; extending southward from six to ten miles into Carbon county and from twenty to twenty-five miles into Natrona county. The botbom of this depression is 800 feet below the rim near the head and over 1700 feet below it near the Platt River. The drainage is practically confined to Camp Creek which rises at the southern end of the Hole; but which affords water for only a portion of the year, and Bates Creek which rises in the Laramie Mountains and furnishes quite a stream. The country about this area is comparatively level; but to the eastward only a few miles rise the Laramie Mountains, and to the westward the Indian Grove and other ranges, which are made up of Mesozoic, Paleozoic, and Archean rocks. In length Bates' Hole varies from twenty-five to thirty-five miles and in width from six to twelve miles;

the lower end being much the wider. The dominant formation entering into the structure of this region is Tertiary; but this rests nearly horizontally upon a very uneven floor of older rocks, which in the central portion have been exposed and suffered extensive erosion. From the rim the slopes are very steep throughout, seldom being less than 15° to 20° and usually much higher and in many instances from 28° to 34°. Occasionally there are vertical walls of the Tertiary rocks from 100 to 200 feet, carved in the most unusual manner and often cut with deep, narrow, dry gorges. Capping the highest Tertiary escarpments there is a heavy conglomerate of unknown age; beneath this are the Titanotherium beds which have a thickness of about 600 feet, and in local depressions in the Cretaceous series underlying this region there is a third series of Tertiary beds, composed of variegated clays and sands that is in all probability Eocene. Along the Platte River all of the Tertiary rocks have been removed and along the Laramie Mountains there are exposed in natural order, Cretaceous, Jurassic, Triassic, Carboniferous, Cambrian, and Archean as one ascends the range. Along the Tertiary escarpments are numerous stunted pines (*Pinus flexlis*) whose roots are exposed from one to eight feet which signifies very rapid erosion. This erosion has been very general and data that will aid us in determining the age of Bates' Hole are well in hand. Illustrated with lantern slides.

A Geological Section through the John Day Basin. By JOHN C. MERRIAM, Berkeley, Cal.

The John Day River and its tributaries have exposed in the erosion of their canyons about ten thousand feet of strata, giving a full series of formations from Lower Cretaceous to Quaternary.

The oldest rocks in this region, which are known to the writer, are a series of altered sedimentaries in the northeastern part of the basin. They are pretty certainly of pre-Cretaceous age and are underlain by quartz diorite[1] which is presumably intruded into them.

On Bridge Creek, near Mitchell, a great thickness of Cretaceous is exposed. The lower 2000 to 3000 feet of this section are typical Knoxville. The upper 1000 to 2000 feet are Chico.

Resting upon the Chico, near Mitchell, also showing typical exposures at Clarno's Ferry, is a presumably Eocene formation to which the name Clarno is given. This formation is made up entirely of tuffs, ashes, and lavas. In places it contains many plant remains and is apparently in part a fresh water formation.

---

[1] Determined by Frank C. Calkins.

The John Day formation rests directly upon the Clarno at Clarno's Ferry. The basin in which it was deposited is quite different from that of the Clarno. It probably rests unconformably upon that formation. The Lower John Day beds are considerably contorted in some localities. Ordinarily they are colored a deep red. Fossil remains are exceedingly rare in this division.

The blue-green beds of the Middle John Day are very fossiliferous. They correspond to the Diceratherium beds of Wortman. The Upper or Buff beds of the John Day lap over the middle division and rest in places upon the older formations. The upper division corresponds to the Merycochœrus Beds of Wortman. As *Merycochœrus* does not occur in the John Day, the upper division will be called the Paracotylops Beds. This name is based on the new generic name proposed by W. D. Matthew for the Upper John Day oreodons, originally supposed to be *Merycochœrus.*

The Columbia lava, an extension of the lavas on the Columbia River to the north, rests unconformably upon the crumpled John Day formation. The name Columbia lava should be restricted to this horizon of the lavas in this region, as other beds included in this group belong in some cases to different geological periods.

The Cottonwood (Loup Fork) formation, near 1000 feet in thickness, rests upon the Columbia lava. The Van Horn Ranch plants, which have generally been considered as John Day, are from this horizon. Remains of a true John Day flora, which had not previously been known, were discovered by the University of California expedition in 1900. The discovery of the true stratigraphic position of the Van Horn Ranch flora explains the apparent inverted position of the Neocene formations in central Washington.

Resting on the worn edges of the Cottonwood Beds is the Rattlesnake formation, comprising several hundred feet of gravel, tuff, and lava.

In canyons cut through the Rattlesnake and Cottonwood are several terraces. Remains of elephants and later horses found in the lower terrace deposits show that they were formed in Quaternary time.

The paper was illustrated with lantern slides showing the principal formations and their relations to each other.

The Geology of the Great Basin in Eastern California and Southwestern Nevada. By H. W. Turner, San Francisco, Cal.

The ridges of the western edge of the Great Basin in Nevada and eastern California are usually very complex in structure and composition. They comprise sediments of Paleozoic and Jura-Trias age much disturbed at some points by intrusions of granolites. In Tertiary time there were extensive lakes, and contemporaneous with these lakes and also later are lavas and tuffs in large amounts, chiefly rhyolites, andesites, and basalts.

The formation of the ranges, or at least their latest uplifts, date from the late Tertiary and post-Tertiary time.

They were elevated along normal faults, the valleys being in part subsided areas, often of the nature of rock basins, whose rims are composed of rocks older than the desert detritus.

There are some gneisses pretty certainly of pre-Cambrian age. These gneisses underlie Lower Cambrian sediments rich in fossil remains at some points. There is an extensive chert series containig abundant graptolites supposed to be of Lower Silurian age. There are Lower Trias beds in the Inyo Range and Jurassic limestone in the Pilot Mountains.

The Tertiary lake beds contain abundant plant, molluscan, and fish remains.

The paper was illustrated with lantern slides.

Notes on the Geology of the Three Sisters, Oregon. By H. W. Fairbanks, Berkeley, Cal.

The Three Sisters form a group of volcanic peaks upon the summit of the Cascade Range, in central Oregon. They rise to a height of about ten thousand feet, and are quite similar in many respects to the other great volcanic peaks which mark the crest of the Cascade Range through Oregon and Washington.

This group of peaks is marked by the presence of a glacier nearly three miles long and half a mile wide.

To the north of the peaks recent volcanic activity is indicated by extensive flows of basic lavas. Volcanic eruptions have occurred since the glacial period, as shown by the relation of the lavas to the grooved and polished surfaces. A volcanic cone upon the North Sister lies in the path of the present glacier.

Illustrated by lantern slides.

A Sketch of the Pedological Geology of California. By E. W. HILGARD, Berkeley, Cal.

Owing to the great climatic diversity, the rainfall varying from two inches at the south to as much as eighty inches in the north, even a sketch of the soil conditions of California must take the climates into consideration. The cardinal difference between rock decomposition in arid as compared with humid climates lies in the retardation of kaolinization, as exemplified in the monoliths of Egypt and the granites of the Sierra Madre, as compared, *e. g.*, with the Alleghanies. Hence in northern California and on the higher Sierra Nevada we find loams and clay soils, while at the lower levels and in southern California the soils are "dusty" or sandy, except where derived from preëxisting clay formations, which give rise to "adobe," and in the upper valleys of the rivers of the Sierra, which carry the materials from the higher levels.

Throughout the middle and southern parts of the state, where no rains of consequence fall between May and November, not only is the soil mass usually of extraordinary depth, but is scarcely changed for several, sometimes for four to ten, feet. There is practically no subsoil in the usual sense, in the absence of clay; water, roots, and air penetrate together to depths impossible in the regions of summer rains, and hence the extraordinary endurance of drought, even by plants foreign to the arid region. Moreover, these soils almost universally contain high percentages of lime and potash, due to the absence of the leaching process, which, on the other hand, results in the formation of "alkali soils," too complex a subject to be dealt with here.

"*Sand*" in the arid soils is not merely quartz grains, but consists of all the original minerals, superficially decomposed. Hence sandy lands are here fully as rich as clay lands are elsewhere.

In the Great Valley it is easy to recognize by their microscopic characters the alluvial areas of the several rivers coming in from the Sierra. Even here the greater rainfall of the Sacramento is evidenced by loam and clay lands, as compared with the San Joaquin valley, where sandy and silty lands prevail altogether. As the rainfall decreases toward the Coast Ranges, the "lightest" are found under the arid lee on the west border of the valley. In its axis, in the "tule lands," as well as on the borders of the bays near its outlet, heavy clay soils are being formed in the slack water, while the streams coming from the Coast Ranges are bordered by light silty lands, the "truck lands" from

Often the fragments differ enough in color from one another, or from the ground mass, so that the brecciated character is plainly visible to the naked eye. In the stone of Weston, for example, the ground mass is gray, the enclosed fragments blue. In the stone of Siena the angular fragments are of a dark color and the enclosing magma is light colored, while of Bandong, Saint-Mesmin and others the reverse is true. In other meteorites the two components differ chiefly in grain and coherence, as in the meteorites of Jelica, Manbhoom, and Soko-Banja. In these the ground mass is of a somewhat coarse, friable character, while the enclosed fragments are of a dark, fine-grained rock. In regard to the ground mass of other brecciated stone meteorites it may be stated that it may itself be made up of rock splinters, *i. e.*, have a tuffaceous character, or it may be crystalline or half glassy. The half glassy ground mass of the Orvinio and Chantonnay meteorites, as already noted, shows a distinct flow structure around the fragments which it encloses.

AGGLOMERATED, SANDSTONE-LIKE AND TUFFACEOUS STRUCTURES.

These may be said to differ from brecciated structure only in the smaller size of the component fragments. The fragments may range from the size of small peas in meteorites of agglomerated structure through that of coarse sand in those which are sandstone-like to that of splinters and fine dust in the tuffaceous meteorites. In the agglomerated meteorites it is often possible to recognize different kinds of rocks. Thus in the Parnallee meteorite Meunier believes he has recognized seven distinct lithologic types. Of the sandstone-like meteorites that of Chassigny is the best example. It is made up of rounded grains of the size of coarse sand. The Shergotty and Ibbenbühren meteorites are likewise granular in appearance. Not all observers, however, agree that the above are clastic in their origin. The tuffaceous structure is a common one in meteorites, Tschermak, as already noted, regarding practically all stony meteorites as of this nature. The resemblance of these to terrestrial volcanic tuffs is very close, though the stratification which usually characterizes the latter has never been observed. The tuffaceous meteorites are made up of splinters and dust varying in degree of consolidation. They are often finely porous so as to soak up fluids readily. The splinters of which they are made up may be similar in character (Shalka) or strikingly dissimilar (Luotolaks).

O. C. FARRINGTON.

(To be continued)

EDITORIAL

THE thirteenth meeting of the Geological Society of America, held in Albany, N. Y., was very satisfactory. The location was sufficiently central to insure a good attendance, the hotel accommodations were excellent and convenient to the place of meeting, and the number of papers was not more than could be read and discussed within the time of the meeting. The local committee, Dr. F. J. H. Merrill and Dr. J. M. Clarke, are to be congratulated on their hospitality and the success of their arrangements.

The postponement of President Dawson's address to the last day of the meeting was regretted by those who were unable to remain through the three days. It would seem advisable to have the presidential address delivered on the second day of the meeting, when there is the greatest number of members present.

The most notable feature of this meeting of the Geological Society, in the city that is looked upon as the cradle of American geology, was the conspicuous absence of a suitable monument to the memory of those pioneers of geological science who have opened a highway to stratigraphy through New York state, and have made of the state a corner stone of the geological structure of the whole country. Such a monument should take the form of a building in which not only the names and records of New York's venerated geologists may be inscribed and their collections preserved, but where their labors may be carried forward and from which inspiration and assistance may spread to geological workers throughout the state. In a state less than New York the absence of such a monument might pass unnoticed.

J. P. I.

THE second annual meeting of the Cordilleran section of the Geological Society of America was held on December 28 and 29. The morning session on the 28th took place in the council room of the California Academy of Sciences, in San Francisco. For the succeeding three sessions the members gathered in the rooms of the Geological Department of the University of California.

The following persons were present at the meeting of the section:

W. P. Blake, E. W. Claypole, A. S. Eakle, H. W. Fairbanks, E. W. Hilgard, W. C. Knight, A. C. Lawson, H. W. Turner, F. M. Anderson, W. C. Blasdale, F. C. Calkins, H. W. Furlong, O. H. Hershey, G. D. Louderback, C. F. Newcombe, W. J. Sinclair, J. C. Merriam.

At the first session Professor Wilbur C. Knight was elected chairman, Professor Andrew C. Lawson, secretary, and Dr. A. S. Eakle, councilor for the ensuing year.

In the course of the four sessions the following papers were read and discussed:

The Evidences of Shallow Seas in Paleozoic Time in Southern Arizona. By W. P. BLAKE, Tucson, Ariz.

In the mountain ranges of southern Arizona there is abundant evidence of shallow seas and shore lines in Paleozoic time. These shores were not, perhaps, a continental margin, but rather the borders of islands, crests of submerged mountain ranges rising at intervals above the Paleozoic ocean and with a trend or direction corresponding eventually to the direction of the mountain ranges of the region.

A cross-section of the territory northeasterly from the Gulf of California shows a succession of mountain ranges, some fifteen in number, in most of which ancient sandstones and conglomerates of Paleozoic age have been identified. Many of the exposures of quartzite are very thick, and these quartzites generally rest upon a coarse-grained porphyritic granite. Deep-sea deposits are not wanting. Thick beds of limestone, especially those of the Carboniferous, give evidence of depressed areas and of oscillations of level. So, also, the existence of thick, uplifted beds of graphitic coal in the Chiricahua Mountains bear testimony to the former existence of land areas, and show a far western extension of the vegetation of the Carboniferous.

Two localities of Devonian beds were described; one in the Santa Ritas and another at the northern end of the Santa Catalina Mountains.

The probable existence of Cambrian beds at several places was pointed out and the ancient tabular gneissic rocks of the Catalinas were referred to the Archean, and regarded as probable equivalents of the Huronian and Laurentian.

The Sierra Madre near Pasadena. By E. W. CLAYPOLE, Pasadena, Cal.

The paper opened with an expression of the surprise with which geologists who have worked principally in the East witness the enormous development and the excessive diastrophism exhibited by Tertiary and even by very late Tertiary strata in the West, and these characters are as well seen in California as in any other western state. The whole Tertiary period has apparently been signalized by thick accumulation, with alternate elevation and depression. Not less has its passage been characterized by volcanic outbursts of intense energy and by quiet outflows of lava almost unequaled in massiveness and extent.

Two great mountain ranges diverging in the north and meeting again in Kern county, inclose between them the San Joaquin Valley. This southern meeting forms one of the great natural features of the state — the Tehachapi Divide.

Speaking now only for the southern part of the state, there seems ample ground for the belief that these ranges have existed from at least Cretaceous if not from earlier Mesozoic time. It is not otherwise easy to find a source for the enormous Pliocene, Miocene and Eocene accumulations of the Pacific margin so far from the Sierra Nevada.

Thick gneissic strata of two types, and standing nearly vertical, compose the range of the Sierra Madre near Pasadena. That to the south contains a large proportion of hornblende, weathers rapidly and deeply, and is consequently eroded with comparative facility. That to the north is largely feldspathic, contains little hornblende, and of it consist the white crags that stand out so boldly on the upper slopes. The former of these masses cannot be less than 2000–3000 feet thick, but it does not rise in the mountain to a greater height than 3500 feet.

Of the wreckage from these two gneissic masses the material filling the valley of Pasadena is composed. From great bowlders near the

The greenstone, designated the Kawishiwin, is the oldest known rock in the state, and is supposed to represent a portion of the original crust of the earth. With its associated volcanic rocks it occurs in two main belts. The southern belt begins in the vicinity of Gunflint Lake and extends westward by way of Gobbemichigamma Lake, the Kawishiwi River, and White Iron Lake, to Tower, and indefinitely westward. The northern belt of greenstone enters the state from Hunters' Island, appearing conspicuously at the south side of Basswood Lake. At Pipestone Rapids and Fall Lake it widens southward and apparently unites at the surface with the southern belt, the overlying Upper Keewatin being absent for a distance of a few miles. But further west it is again divided by the Stuntz conglomerate, the northern arm running to the north of Vermilion Lake, west of which its extension is unknown, and the southern one running south of the lake.

The fragmental stratified rocks of the Lower Keewatin are most important toward the western part of the area of exposure of crystalline rocks. They occupy a wide area, south, west, and north of Tower. The iron ores of Tower and Ely on the Vermilion iron range occur in the upper part of the Lower Keewatin. It is probable that the immediately enclosing rock is a sedimentary one, although composed of the elements of a basic eruptive. The sediments extend south to the Giants Range of granite, where they are metamorphosed to mica-schists by the granite. Toward the west they extend as far as the Mississippi River and its northern tributaries and across the Bowstring, although the drift prevents the delimitation of the belt. To the northwest they extend toward Rainy Lake, in this direction being converted into mica-schists and gneisses by the intrusion of granite; in unmodified form they are found at one point only on Rainy Lake. These fragmental rocks of the Lower Keewatin doubtless also underlie most of the central and southwestern part of the state as far as the Minnesota River. Here they dip beneath the later formations in the southwestern portion of the state, and probably occupy a wide patch in South Dakota. South of the Giants Range they occur also, but as they are covered by the gabbro and Animikie toward the east and the drift deposits of the St. Louis valley toward the west their geographic boundaries are mostly unknown. They appear in the central and western portions of Carlton county, where their line of separation from the Upper Keewatin is quite obscure, and in the central and western portions of Morrison county. The Lower Keewatin marble is seen at Lake Ogishke-Muncie and at Pike Rapids on the Mississippi.

The Lower Keewatin was terminated by a period of extensive folding and intrusions of granite and basic rocks.

The Pewabic quartzite belongs with the Keewatin, but whether to the Lower or Upper Keewatin is not known. This formation includes altered quartzites and iron-ores between the granite and gabbro in the immediate vicinity of Birch Lake and small patches of similar rocks in Sec. 30–62–10; on the south shore of Disappointment Lake; on the north shore of Fraser Lake; on the south shore of Gabbemichigamma; at Akley Lake, forming the so-called Akley Lake series extending from the west side of Sec. 34–65–5 to the eastern part of Sec. 27–65–4.

The Upper Keewatin occurs in troughs in the Lower Keewatin, and particularly in one main trough the axis of which is traceable from Vermilion Lake to Saganaga Lake. The northern arm of this syncline, consisting of granites, gneisses, associated mica-schists, and in some places earlier greenstones, extends from the northern part of Vermilion Lake through Basswood Lake to the northern side of Hunter's Island. The southern arm, consisting of Lower Keewatin green-schists and other schists, penetrated by the granite of the Giants Range, extends from Pokegama Falls on the southwest toward the northeast, until cut out by the encroachment of the gabbro from the south. The Upper Keewatin consists very largely of conglomerates, but also includes graywackes, argyllites, quartzites, and jaspilites, in general coarser than those of the Lower Keewatin. Volcanic rocks are less important than in the Lower Keewatin, although still present. There is no general order of succession in the Upper Keewatin excepting that it can be said that it is in general conglomeratic at the bottom.

After Upper Keewatin time both the Lower and Upper Keewatin were subjected to another folding, the axis of which had a general parallelism with the earlier folding, with the result that the Upper Keewatin lies in narrow synclines in the Lower Keewatin and in places is nearly or quite vertical.

Associated with the Keewatin rocks are granites of at least two periods of intrusion, one later than the Lower Keewatin and one later than the Upper Keewatin. The later granite is believed to be represented by the higher parts of the Giants Range and the Snowbank Lake granite. The earlier granite is represented by the granites at Kekequabic Lake, Saganaga Lake, Basswood Lake, Burntside Lake, Vermilion Lake, Lac la Croix, and Kabetogoma Lake. The origin of the granite is discussed and the same conclusions reached as in a previous article.[1]

The Taconic.—This is unconformably above the Keewatin rocks. It comprises the Animikie and Keweenawan divisions.

The Animikie rocks enter the state at Pigeon Point, run westward along the international boundary to the eastern part of Secs. 22 and 27 T. 65 N., R. 4 W. They reappear again southwestward from Birch Lake on the northwest side of the gabbro mass, and thence continue along the south side of the Giants Range, constituting the Mesabi iron series, to Pokegama Falls. The higher parts of the Animikie are best developed toward the east, while the lower parts are best developed toward the west.

The Animikie rocks comprise the Pokegama quartzite, Mesabi iron-bearing formation, some limestone and slate, all strictly conformable with one another. The thickness is several hundred feet, sometimes reaching nearly 1000 feet. The dip of the series is uniformly to the south, 8° to 12°.

The iron-bearing formation and the Pokegama quartzite constitute the base of the formation. The quartzite in places is beneath the iron formation; in other places it is in the same horizon; and in still others is above the iron formation. Commonly the base of the Animikie is marked by a conglomerate, containing débris from the underlying Keewatin rocks. This is a narrow horizon which soon graduates upward into a quartzite, known as the Pokegama quartzite, from its typical development near Pokegama Falls on the Mississippi River. The thickness of the quartzite is not known to exceed fifty feet, and is sometimes less than twenty-five feet.

Above the quartzite, or in alternating beds with it, or below it, appears the iron-bearing or taconyte member of the Animikie, which contains the iron ore deposits of the Mesabi iron range. The ore is usually hematite in the western part of the range and magnetite in the eastern part. It was previously supposed to have been derived from the alteration of a greenish glauconitic sand-rock; but later work has seemed to show that the green-sand is a volcanic sand, and that the so-called taconitic rock itself has resulted from igneous forces. This is accounted for by supposing a chain of active volcanoes to have existed where the Mesabi iron range is now found. These volcanoes yielded flows and ejectamenta to the adjacent waters which have been modified into the various phases of the iron formation now seen. This volcanic epoch may have a deep-seated connection with the Cabotian or lower division of the Keweenawan (described later).

---

[1] The origin of the Archean Igneous Rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299-310. Summarized JOUR. GEOL., Vol. VII, 1899, p. 194.

Above the iron-bearing member is an impure dark colored limestone a few feet in thickness, not exceeding twenty. It extends apparently the whole length of the Mesabi range, but has been identified in two places only, Sec. 7, T. 58 N., R. 17 W., and doubtfully on the shores of Gunflint Lake. This limestone may be regarded as the basal horizon of the next overlying rock.

The black slate is probably several thousand feet in thickness and constitutes the bulk of the Animikie. In the neighborhood of Gunflint Lake it has been divided by Dr. Grant into a lower black slate division and an upper graywacke-slate division, both of which members are interleaved with diabase sills.

In the Indian reservation at Grand Portage and at various places along the Grand Portage trail is a graywacke, which is supposed to overlie the black slate member, but its extent and stratigraphical position have not been satisfactorily established.

The top of the Animikie has not been identified. The first recognizable datum plane after the close of the Animikie is the Puckwunge conglomerate, supposed to be the fragmental base of the Keeweenawan.

At one or two places southwestward from Birch Lake, and at Little Falls on the Mississippi River, and in Morrison county, the Animikie has been converted into a mica-schist.

The age of the Animikie is believed to be Lower Cambrian for the following reasons: It graduates upward into Upper Cambrian rocks as seen on the south side of Lake Superior. The derivation of the iron ores from a glauconitic green-sand indicates that large quantities of foraminiferal organisms once lived in the Animikie ocean, and Matthew has shown the existence of foraminiferal organisms associated with the iron ore in the St. Johns group of New Brunswick. Further the Animikie has a uniformly low dip, while the lower strata are all highly tilted. There must therefore have been a great lapse of time between the deposition of the two series.

The Keweenawan.—The Puckwunge conglomerate is taken to be the *fragmental* base of the Keweenawan, although certain igneous rocks which antedate it and which perhaps are contemporaneous with the upper portions of the Animikie are also called Keweenawan. The conglomerate is found at Grand Portage Island, at Isle Royale, on the Baptism River, at Little Marais, on Manitou River, at the deep well at Short Line Park near Duluth, and at New Ulm.

Above this conglomerate are conglomerates and sandstones of Keweenawan age which are stratified with lavas of diabasic nature. Still higher up the eruptive rocks become less in quantity and the fragmental rock is a sandstone, known as the Hinckley sandstone, quarried in the gorge of the Kettle River in Pine county. This in turn grades up into typical Upper Cambrian sandstones of the St. Croix valley. The term Potsdam is restricted to the Puckwunge conglomerate and the hardened quartzites immediately overlying it, represented by the Sioux quartzite, the Baraboo and Barron county quartzites of Wisconsin, the quartzite at Grand Portage Island, and west of Grand Portage village, the New Ulm quartzite in Cottonwood county, and the quartzite in Pipestone county.

The igneous rocks of the Keweenawan vary in age from the late Animikie time to the top of the Keweenawan series. They are divided into two groups, the Cabotian or Lower Keweenawan, and the Manitou or Upper Keweenawan.

The Cabotian division includes gabbro and contemporaneous red rock and their surface lavas, and all other dikes and sills which are associated with, but younger than, the Animikie clastic rocks, and which are older than the Puckwunge conglomerate. The lower member of the Cabotian is the gabbro, which covers an enormous area. It extends on the east to East Greenwood Lake in T. 64, N., R. 2 E. On the north it is bounded by the Animikie strata of the Mesabi iron range. Its westernmost exposure is in the vicinity of Short Line Park, Duluth. The southern limit is irregular, swinging from East Greenwood Lake in a zigzag manner through T. 63 N., R. 1 W., T. 62 N., R. 2 W., T. 62 N., R. 4 W., T. 60 N., R. 6 W., T. 60 N., R. 7 W., T. 58 N., R. 10 W., and T. 55 N., R. 11 W., to Duluth.

Along the northern and northwestern side of the great gabbro mass, the gabbro is plainly intrusive on the older formations, Animikie and Keewatin.

From the northern border of the gabbro many sills offshoot and penetrate the Animikie strata parallel to the bedding. These are known as the Logan sills.

Near its contact with the underlying rocks, both the Animikie and Keewatin series, there are various altered rocks which can be connected in places with the gabbro and in places with the underlying rocks. To these altered rocks the term muscovadyte has been applied. It includes the various so-called peripheral phases of the gabbro.

On the southern and eastern border the gabbro is penetrated by and penetrates in a confused manner the red rock, with which it alternates both structurally and areally. It is believed to have resulted from the metamorphism by the gabbro of the Animikie, and perhaps earlier fragmentals.

As the granites of the Archean are believed to have resulted from the softening of acid fragmentals, so the gabbro may probably have been the result of the metamorphism or re-fusion of the Keewatin greenstones.

The anorthosite masses of the Beaver Bay diabase, supposed by Lawson to be of Archean age and to underlie unconformably the Beaver Bay diabase, are believed to represent segregation phases in the main gabbro flow, and to be the same as anorthosite masses in the gabbro proper to the west.

The Beaver Bay diabase is believed to represent the upper portion of the great gabbro flow, and to be due to the first and greatest movement of the gabbro toward Lake Superior. The Logan sills belong to this part of the gabbro flow.

The Manitou division of the Keweenawan includes the surface flows, sills, and dikes which accompanied and followed the Puckwunge conglomerate. These eruptives, with the clastics associated with them, do not have a thickness in Minnesota of more than 1000 feet. These lava sheets extend along the shore of Lake Superior from near Baptism River to near Grand Marais, except where replaced at intervals by the Beaver Bay diabase or some of the intersheeted fragmentals. They occur also in the neighborhood of Grand Portage Bay, but their extent here is not definitely known.

General.—The most important petrological conclusions determined from the examination of the Minnesota crystalline rocks, are three in number:

1. All the granites of the Archean can be explained on the assumption that they are intrusives representing the metamorphosed conditions of clastic rocks adjacent to the observed intrusions, rendered plastic by the force of dynamic metamorphism accompanied by moisture.

2. The basic Keweenawan gabbro and its derivatives are derived from the metamorphism and complete re-fusion of the Archean greenstones and their attendants.

3. The green-sand of the Mesabi iron-bearing formation appears to have resulted from a volcanic sand and the taconite itself from igneous forces.

Comment.—The three main petrological conclusions announced by Professor Winchell as the most important results of his final petrological work, summarized in the closing general paragraph, would be dissented from by most of the other geologists who have worked in this area.[1]

The Cambrian age of the Animikie strata has long been maintained by Professor Winchell, and above are summarized his arguments in support of this position. The first argument, that the Animikie grades into the Upper Cambrian rocks, is not in accord with the observations of most of the geologists above referred to. The second argument, based on the similarity of the unaltered green-sand in the Mesabi district with that in the Cambrian of the eastern United States, loses weight when we consider the fact that the similarity is not great, the differences being many and significant; and if the similarity were complete, the correlation would involve laying too much stress on lithological similarity of widely separated formations. Professor Winchell's latest conclusion, that the Mesabi green-sand is volcanic and not organic, while entirely dissented from by others who have studied this rock, in itself spoils his argument based on similarity. The third argument in favor of the Cambrian age of the Animikie, based on the extent of the unconformity beneath the Animikie, has little value when unsupported by the other lines of evidence. Professor Winchell's conclusion as to the Cambrian age of the Animikie strata is thus not adequately sustained by the reasons given. The view that the Animikie is Upper Huronian (pre-Cambrian) is the commonly accepted one. The evidence favoring this view is summarized by Van Hise.[2]

Further comment on the above work would require reference to the detailed observations made in northeastern Minnesota during the past four years by the Lake Superior Division of the United States Geological Survey.[1] The results of this work have not been published and any reference to the conclusions reached would be premature. In general it may be stated that now, as in the past, there is divergence in the conclusions reached by the Minnesota Survey and by the United States Geological Survey concerning the position and importance of the unconformities, correlation of series, and nomenclature.

---

[1] Some of these geologists are: R. D. Irving, C. R. Van Hise, J. Morgan Clements, W. S. Bayley, U. S. Grant, J. E. Spurr, A. H. Elftman, C. K. Leith.

[2] Correlation Bulletin, Archean and Algonkian, No. 86, U. S. Geol. Survey; Principles of Pre-Cambrian Geology, Sixteenth Annual Report, U. S. Geological Survey.

C. K. LEITH.

The Norwegian Polar Expedition, 1893 to 1896. Scientific Results. Edited by FRIDTJOF NANSEN. Vol. I. Longmans, Green, & Co.

The object of the report of which this is the first volume is stated in the preface to be "to give in a series of separate memoirs a complete account of the scientific results of the Norwegian North Polar Expedition of 1893 to 1896." The first volume contains the following papers: "The Fram," 16 pp. with three plates; "The Jurassic Fauna of Cape Flora, Franz Josef Land," by J. F. Pompeckj, with a "Geological Sketch of Cape Flora and its Neighborhood," by Fridtjof Nansen, 147 pp. with three plates; "Fossil Plants from Franz Josef Land," by A. G. Nathorst, 26 pp. with two plates; "An Account of the Birds," by Collett and Nansen, 53 pp. with two plates; "Crustacea," by G. O. Sars, 137 pp. with thirty-six plates.

The fossil fauna brought back from Cape Flora was collected by Nansen during the period of his stay with Jackson at Elmwood, Cape Flora, Franz Josef Land. The collection was studied by J. F. Pompeckj, whose descriptions of the fossils constitute the second part of the volume. Collections from the same localities secured by the Jackson-Harmsworth expedition were examined and described by Mr. E. T. Newton, but the conclusions reached by Pompeckj and by Newton as to the age of the strata are somewhat at variance.

The condition of preservation of the fossils is poor, and many species, particularly of lamellibranchs, could not be identified even generically. The collection shows that a fauna of at least twenty-six different species occurs in the Jurassic sediments about Cape Flora.

---

[1] The reports on this area in preparation by the survey are: Lake Superior Iron Ores, to appear in the Twenty-first Annual Report; Monograph on the Vermilion Iron Bearing District of Minnesota, and Monograph on the Mesabi Iron District of Minnesota.

The collections of the Jackson-Harmsworth expedition fro region only afforded fourteen species, and seventeen of t studied by Pompeckj were not recorded by Newton. The f found at five localities, and at three of these they were *in sit* the results of his study of the Jackson-Harmsworth c Newton concluded that the "Lower Oxfordian rocks," and the equivalent of the "British Kellaway rocks," are represente Jurassic strata underlying the basalt at Cape Flora. Pompe ever, was able to identify four horizons in a much more manner. The lowest of these is Bajocian, and probably th Bajocian; the second is Lower Callovian, the zone of *Macroc macrocephalus;* the third is the Middle Callovian, the zone of *Ca milaschewici;* and the fourth is Upper Callovian, the zone of *Qu toceras lamberti.* The Bajocian fauna is apparently without ana the arctic region, but seems to show direct affinities with the European Jura. The Callovian faunas are very near those o Russian Callovian, and these two regions were probably in communication during that part of Jurassic time. It is worthy o that there is hardly any likeness between the fauna of Cape Flora that of Cape Stuart, East Greenland.

In the fossils, one rather striking feature is the paucity of ga pods, one species only having been found in the marine fauna, w cephalopods and lamellibranchs are relatively much more abund This general relation also holds for the arctic fauna of north Europe.

The identification of these beds at Cape Flora gives the norther most locality of Jurassic beds, since the latitude of Cape Flora nearly 10° farther north than that of the next most northerly depo of this age. These beds show that the Bajocian sea of north Europ extended far to the northward. Spitzbergen was probably not covered; neither was Novaja Semlja, and these two islands were probably connected with each other and with Europe. This land area may have been extended northward to Franz Josef Land. The sea seems to have lain north and west of this land. The Petchora Basin sea is conjectured to have extended north between Spitzbergen and Novaja Semlja, and to have been bounded on the north by land in the region of Franz Josef Land. Spitzbergen is conjectured to have been connected with the Franz Josef Land of the Callovian epoch. The Callovian sea is conjectured to have extended east to Alaska. Toward the end of the Callovian epoch the sea receded to the southward from Franz Josef Land, while Spitzbergen and Novaja Semlja were partly submerged.

The main body of the sedimentary Jura of Cape Flora extends from sea level up to 575 feet. It is fossiliferous in horizons only. The Callovian part of the Jura extends from 370 feet to 575.

The fossil plants secured by Nansen, also from the region about Cape Flora, were placed in the hands of A. G. Nathorst, and his report upon them constitutes Part III of the volume. These plant remains are all fragmentary and very poorly preserved, so that in most instances no specific identification could be made. Out of the twenty-nine forms recognized, only two are specifically identified with certainty, though seven others are compared with described species. The conclusions reached by Nathorst as to the age of the plant-bearing deposit is that "it was formed toward the close of the Jurassic or commencement of the Cretaceous period, without our being able at present to settle which." The fossil plants occur in two beds which lie between certain of the seven extrusive basaltic flows.

The account of the birds is divided into four sections, the first treating of the journey along the north coast of Siberia; the second gives the observations made while the "Fram" was drifting with the ice before Nansen left it; the third gives the observations made during the sledge journey of Nansen and Johansen; while the fourth gives the observations made on the "Fram" after Nansen left it in March 1895. This section of the report is a technical description of the species of birds seen.

The section on the Crustacea is in much detail and will be of great interest and value to zoölogists. The conclusion is reached that the bulk of the pelagic animals found in the North Polar basin were derived from the west through the Atlantic current flowing in beneath the superficial Siberian current. It has also been found that forms which have hitherto been regarded as quite southern in distribution are found in the polar sea.

The volume also makes some announcement of the contents of future volumes of the report. The second volume is announced to contain "The Astronomical Observations and their Results," "Terrestrial Magnetism," and "Pendulum Observations and their Results." The third volume will deal with "The Oceanography of the North Polar Basin," "Hydrometers and their Errors, especially those caused by the Variation of the Surface Tension of Liquids," "The Depths and Submarine Features of the North Polar Basin, with chemical Analyses and Microscopical Composition of the Deep Sea Deposits," "Diatomaceæ and Algæ living on the Drifting Ice and in the Sea of the North Polar Basin." Many other memoirs are announced for still later volumes. It is stated that the number of volumes will probably be five or six, which it is hoped may be finished in the course of about two years. These volumes will not only furnish a large body of information about a little-known region, but some of them will deal with questions of world-wide application. The reports are to be issued in the English language only.

R. D. S.

The Pleistocene Geology of the South Central Sierra Nevada, with especial reference to the Origin of the Yosemite Valley. By HENRY WARD TURNER. Proceedings of the California Academy of Sciences. Third Series, Vol. I, No. 9; 9 Plates; pp. 361–321.

This paper gives a brief outline of the pre-Pleistocene orogenic history of the Sierra Nevada, the orogenic movements of the Pleistocene, and a brief sketch of the Pleistocene history of the region, as an introduction to the discussion of the origin of the Yosemite Valley. The Sierran period, the period of high lands preceding glaciation, is included in the Pleistocene. Some brief notes on the glacial period are also given, and the conclusion reached that there were two periods of glaciation separated by an interval of deglaciation, though the evidence on this point is not looked upon as altogether conclusive. The assumption that in the interior of the continent there were two (and not more) well-marked glacial epochs, needs to be modified in the light of the investigations of the last few years. The brief statement concerning the cause of the glacial period, also seems not to take account of the latest and most satisfactory views on this subject.

The several hypotheses which have been advanced concerning the origin of the Yosemite are considered, and the conclusion reached that this valley was not scooped out by the ice (Muir); that it is not a river-cut canyon, the walls of which were made vertical by the sapping action of ice (Johnson); and that there is no adequate evidence that it is due to a drop fault (Whitney, *et. al.*); but that it owes its origin to river erosion influenced, in its topographic results, by the strong jointing of the rock of the region. This view, however, does not preclude the glaciation of the valley, but ascribes to the ice a very insignificant part in its excavation. R. D. S.

A Record of the Geology of Texas for the Decade ending December 31, 1896. By FREDERIC W. SIMONDS, PH.D. Reprint from Vol. III of the *Transactions of the Texas Academy of Science.* [Austin ?], August, 1900, pp. 280.

In 1887 the U. S. Geological Survey published Bulletin No. 45, by Professor R. T. Hill, upon "The Present Condition of Knowledge of the Geology of Texas." Although that bulletin was not a bibliography in the ordinary meaning of the word, it mentioned the chief publications upon the geology of the State of Texas up to 1886, and gave the general results of the work of the authors. The present volume by Dr. Simonds is an annotated bibliography covering the succeeding ten years. That particular decade has been the most fruitful period in the history of geological investigation in the State of Texas, and, as a consequence, Dr. Simonds' list is the most important one that could have been made of any limited period.

No one who has attempted a piece of bibliography will fail to appreciate this valuable contribution to geologic literature. Such publications represent a great deal of dead-work, much of it of a dreary kind. But Professor Simonds has rendered a genuine service both to the people of Texas and to the science of geology by bringing these titles together and giving a résumé of the contents of each paper. As a rule but few persons know just what has been published upon the geology of a given state, or where to lay hands upon it. This list fills the want, so far as Texas is concerned during the period 1886–1896.

The titles are arranged according to the alphabetic order of the authors, and there is an index of both authors and subjects at the end of the volume.

J. C. BRANNER.

RECENT PUBLICATIONS

—BOULE, MARCELLIN. Étude Paléontologique et Archéologique sur la Station Paléolithique du lac Karar (Algerie). Extrait de "L'Anthropologie." Tome XI, 1900. Paris.

Feuille de Figeac. Extrait du Bulletin 73 des services de la Carte géologique de la France et des Topographies souterraines. Mai 1900.

Note sur la Physiographie du Carladez. Extrait des Documents Historiques relatifs à la Vicompte de Carlat. 1899.

Variétés. Extrait de "L'Anthropologie."

—BRIGHAM, ALBERT P. Glacial Erosion in the Aar Valley. (Abstract with discussion.) [From Bulletin Geological Society of America, Vol. II, 1899.]

Note on Trellised Drainage in the Adirondacks. Reprinted from the American Geologist, Vol. XXI, April 1898.

—CHESTER, ALBERT H. A Dictionary of the Names of Minerals, including their History and Etymology. John Wiley & Sons, New York.

—CROSBY, W. O. Report on Borings for the East Boston Tunnel.

—DORSEY, CLARENCE W., and J. A. BONSTEEL. Soil Survey in the Connecticut Valley. Reprint from Report No. 64 of the Department of Agriculture. Field Operations of the Division of Soils in 1899. Washington, 1900.

—ELLIOT, G. F. SCOTT, and J. W. GREGORY. The Geology of Mount Ruwenzori and Some Adjoining Regions of Equatorial Africa. [From the Quarterly Journal of the Geological Society for November 1895. Vol. LI.)

—GARWOOD, E. J., and J. W. GREGORY. Contributions to the Glacial Geology of Spitzbergen. [From the Quarterly Journal of the Geological Society for May 1898, Vol. LIV.) Plates XIII–XIX.

—Geological Society of America, Bulletin of. Proceedings of the Twelfth Summer Meeting, held at New York City, June 26, 1900. By H. L. Fairchild, Secretary, Vol. XII, pp. 1–12. Rochester, 1900.

—Geological Survey of Canada, Index to Reports, 1863 to 1884. Compiled by R. B. Dowling. Ottawa, 1900.

—Geological Survey of Michigan, Annual Report to the Board of. By Albert C. Lane, State Geologist, 1899. Also, The Origin, Properties, and Uses of Shale; by H. Ries, Special Agent for the State Geological Survey. [Reprinted from the Michigan Miner, Vol. I, No. 12; Vol. II, Nos. 1 and 3, November 1899 to February 1900.]

—Geology. Reprint from Norway. (Official Publication for the Paris Exhibition, 1900.)

—GREGORY, J. W., D.Sc., Melbourne. Contributions to the Geology of British East Africa. Part I, The Glacial Geology of Mount Kenya. Reprinted from the Quarterly Journal of the Geological Society for November 1894, Vol. I.

Excursion to Sudbury. Reprinted from the Proceedings of the Geologists' Association, Vol. XV, Part 10, November 1898.

The Physical Features of the Norfolk Broads. Reprinted from Natural Science, Vol. I, No. 5, July 1892.

The Plan of the Earth and its Causes. Reprinted from the Geographical Journal for March 1899.

—HERRICK, C. L., and D. W. JOHNSON. The Geology of the Albuquerque Sheet. With a Map and Plates XXVII–LVIII. Bulletin of the Scientific Laboratories of Denison University. Edited by W. G. Tight. Vol. XI, Article IX, June 1900.

—HOVEY. E. O. Erosion Forms in Harney Peak District, South Dakota. From Bulletin Geol. Soc. Am., Vol. XI, 1899. (Abstract with discussion.)

The Geological and Paleontological Collections in the American Museum of Natural History. Reprinted from Science, N. S., Vol. XII, No. 307, pp. 757–760, November 16, 1900.

Oliver Payson Hubbard. From the American Geologist, Vol. XXV, June 1900.

—Indiana Academy of Science, Proceedings of the. 1898 and 1899. (Two volumes). Edited by George W. Benton.

—LANE, ALFRED C. Dr. L. L. Hubbard. Sketch of one of Michigan's noted State Geologists. Reprinted from the Michigan Miner, December 1, 1900.

The Geothermal Gradient in Michigan. Reprinted from the American Journal of Science, Vol. IX, June 1900.

—LINDGREN, WALDEMAR. Metasomatic Processes in Fissure-Veins. A paper read before the American Institute of Mining Engineers at the Washington Meeting, February 1900.

The Gold and Silver Veins of Silver City, De Lamar, and other Mining Districts in Idaho. Extract from the Twentieth Annual Report of the U. S. Geol. Survey, 1898–9. Part III, Precious-Metal Mining Districts. Washington, 1900.

—McEvoy, James. Report on the Geology and Natural Resources of the Country Traversed by the Yellow Head Pass Route from Edmonton to Tête Jaune Cache, comprising portions of Alberta and British Columbia. Geological Survey of Canada, Part D, Annual Report, Vol. XI, Ottawa, 1900.

—Miller, Alfred Stanley. A Manual of Assaying: The Fire Assay of Gold, Silver, and Lead, including Amalgamation and Chlorination Tests. 16mo. iv+91 pages. New York: John Wiley & Sons.

—New South Wales. Records of the Geological Survey of. Vol. VII, Part I, 1900. Sydney: William Appleton Gullick, Government Printer, 1900.

—New York Academy of Sciences, Annals of the. Vol. XIII, Part I. Editor: Gilbert Van Ingen.

—Oyen, P. A. Bidrag til vore bræegnes geografi. Kristiania: A. W. Bröggers, bogtrykkeri, 1900.

A Glacial Deposit near Christiania. Alb. Cammermeyers Forlag. Kristiania, 1900.

—Packard, Alpheus S. A New Fossil Crab from the Miocene Green-sand Bed of Gay Head, Marthas Vineyard, with Remarks on the Phylogeny of the Genus Cancer. With two plates. Proceedings of the American Academy of Arts and Sciences. Vol. XXVI, No. 1. July 1900.

On Supposed Merostomatous and other Paleozoic Arthropod Trails, with Notes on those of Limulus. Proceedings of the American Academy of Arts and Sciences. Vol. XXXVI, No. 4. July 1900.

—Penck, Albert. The Illecillewaet Glacier in the Selkirks. From the Journal of the German and Austrian Alpine Society. (Translated by D. R. Keyes, Toronto, Canada.) Reprinted from Proceedings of the Canadian Institute. (Read April 29, 1899.)

—Reade, T. Mellard. A Contribution to Post-Glacial Geology. [Extracted from the Geological Magazine, N. S., Decade IV, Vol. VII, pp. 97–105, March 1900.] London: Dulau & Co.

—Reade, T. Mellard and Philip Holland. The Phillades of the Ardennes Compared with the Slates of North Wales. Part II. Reprinted from the Proceedings of the Liverpool Geological Society, 1899–1900.

—Sardeson, F. W. Meteorology of the Ordovician. Reprinted from the American Geologist, Vol. XXVI, December 1900.

—Slaught, Herbert Ellsworth. The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane. Reprinted from American Journal of Mathematics, Vol. XXII, No. 4.

—Stockbridge, Horace Edward. Rocks and Soils: Their Origin, Composition and Characteristics; Chemical, Geological and Agricultural. Second edition, revised and enlarged. New York: John Wiley & Sons.

—Tillman, S. E. A Text-Book of Important Minerals and Rocks. With tables for the determination of minerals. New York: John Wiley & Sons, 1900.

—Turner, Henry Ward. The Pleistocene Geology of the South Central Sierra Nevada with Especial Reference to the Origin of Yosemite Valley. With 9 plates. Proceedings of the California Academy of Sciences, Third Series: Geology, Vol. I, No. 9. San Francisco. Published by the Academy, 1900.

—Upham, Warren. Pleistocene Ice and River Erosion in the Saint Croix Valley of Minnesota and Wisconsin; and Giants' Kettles eroded by Moulin Torrents. Bulletin of the Geological Society of America, Vol. XII, pp. 13–44. Pl. 1. Rochester, December 1900.

—U. S. Department of Agriculture, Division of Biological Survey. North American Fauna, No. 17: Revision of American Voles of the Genus Microtus. By Vernon Bailey. Washington, 1900.

North American Fauna, No. 18: Revision of the Pocket Mice of the Genus Perognathus. By Wilfred H. Osgood. Washington, 1900.

—Ward, Lester F. Elaboration of the Fossil Cycads in the Yale Museum (with Plates II–IV). Reprinted from the American Journal of Science, Vol. X, November 1900.

Status of the Mesozoic Floras of the United States. First Paper: The Older Mesozoic, by Lester F. Ward, with the collaboration of William M. Fontaine, Atreus Warner, and F. H. Knowlton. Extract from the Twentieth Annual Report of the U. S. Geological Survey, 1898–9, Part II--General Geology and Paleontology. Washington, 1900.

—Washington Academy of Sciences, Proceedings of, Vol. II, 1900. Washington, D. C.

Papers from the Harriman Alaska Expedition:

IX. Diptera. By D. W. Coquillett. Vol. II, pp. 389–464.

X. Neuropetroid Insects. By Nathan Banks. Vol. II, pp. 465–476.

XI. Arachnida. By Nathan Banks. Vol. II, 477–486.

XII. Lepidoptera. By Harrison G. Dyar. Vol. II, pp. 487–501.

XIII. Heteroptera. By O. Heidemann. Vol. II, pp. 503–506.

XIV. The Sphegoidea and Vespoidea. By Trevor Kincaid. Vol. II, pp. 507–510.

XV. Orthoptera. By A. N. Caudell. Vol. II, pp. 511, 512.

XVI. Aphididae. By Theo. Pergande. Vol. II, pp. 513–517.

XVII. Formicidae. By Theo. Pergande. Vol. II, pp. 519–521.

XVIII. Coleoptera. By E. A. Schwarz. Vol. II, pp. 523–537.

XIX. Psyllidae. By E. A. Schwarz. Vol. II, pp. 539–540.

A Contribution to the Study of the Insect Fauna of Human Excrement. By L. O. Howard. Vol. II, pp. 541–604.

A Theatrical Performance at Walpi. By J. Walter Fewkes. Vol. II, pp. 605–629.

A Collection of Small Mammals from Mount Coffee, Liberia. By Gerritt S. Miller, Jr. Vol. II, pp. 631–649.

Fossil Land Shells of the John Day Region, with Notes on Related Living Species. By Robert E. C. Stearns.

Preliminary Revision of the North American Red Foxes. By C. Hart Merriam. Vol. II, pp. 661–676.

—WHITEAVES, J. F. Mesozoic Fossils. Vol. I. Part IV. On Some Additional or Imperfectly Understood Fossils from the Cretaceous Rocks of the Queen Charlotte Islands, with a Revised List of the Species from these Rocks. Geological Survey of Canada. Ottawa, November 1900.

—Wisconsin Academy of Sciences, Arts, and Letters, Transactions of the, Vol. XII. Part II. 1899. With 12 plates. Edited by the Secretary, Madison, 1900.

THE

JOURNAL OF GEOLOGY

FEBRUARY–MARCH, 1901

ON THE ORIGIN OF THE PHENOCRYSTS IN THE PORPHYRITIC GRANITES OF GEORGIA[1]

TABLE OF CONTENTS

Introduction.
Description of Individual Areas.
The Fayette-Campbell-Coweta counties porphyritic granite area.
The Hancock county porphyritic granite area.
The Baldwin county porphyritic granite area.
The Warren county porphyritic granite area.
The Greene county porphyritic granite area.
The Columbia county porphyritic granite area.
The Pike county porphyritic granite area.
The Fulton county porphyritic granite area.
Résumé:
  Macroscopic features.
  Microscopic features.
Chemical composition.
Genetic relationship of phenocrysts to groundmass.
  Evidences of Intratelluric origin.
  Evidence of contemporaneous origin.

INTRODUCTION.[2]

UNTIL quite recently, the idea has been prevalent among petrographers, that porphyritically developed minerals (phenocrysts) in intrusive igneous rocks were of intratelluric[1] origin. Indeed, as pointed out by Pirsson, no sharp distinction heretofore has apparently been drawn in the literature, between the origin of phenocrysts in intrusive and extrusive igneous rocks; indicating probably, that the porphyritically developed mineral or minerals were of the same origin in the two rock divisions here designated, and were formed at much greater depths than the place in which they are now found. The idea that phenocrysts in intrusive igneous rocks are not always of intratelluric origin, but have, in many cases, been formed *in place*, and are therefore contemporaneous in origin, with a part at least, of the other rock constituents, was advocated by Zirkel[2] in 1893; by Cross[3] in 1895; and more recently by Pirsson[4] and Crosby.[5]

---

[1] Published by permission of the State Geologist of Georgia.

[2] The writer wishes to acknowledge his indebtedness to Professor A. C. Gill, of Cornell University, for kindly reading and criticising this paper in manuscript.

Pirsson and Crosby are agreed in dissenting from the old and long-accepted theory, that appreciable or abrupt changes in the ratio of cooling and the viscosity of the magma, are essential elements in the development of the porphyritic structure — phenocrysts and groundmass — in intrusive igneous rocks.

A careful field study of the granitic rocks of Georgia, by the writer, during the seasons of 1898, 1899 and 1900, shows a number of extensive areas of coarse-grained porphyritic granites occurring within the limits of the Georgia Piedmont plateau. The distribution of the porphyritic granite areas is given on the accompanying map. The interior gradation or passage of the porphyritic facies, peripherally, into an even-grained coarse-textured non-porphyritic granite of the same mineral and chemical composition, is readily traceable in most of the granite areas.

---

[1] The term "intratelluric" is here used in the same sense as that given it by Pirsson in the Amer. Jour. Science, 1899, Vol. VII, p. 272, "meaning an earlier period and greater depth of the magma than that in which it came to rest."

[2] Lehrbuch der Petrographie, 1893, Vol. I, p. 737 et seq.

[3] Laccolitic Mountain Groups, U. S. Geol. Surv., Fourteenth Annual Report, 1895, p. 231.

[4] On the Phenocrysts of Intrusive Igneous Rocks, Amer. Jour. Science, 1899, Vol. VII, pp 271–280.

[5] On the Origin of Phenocrysts and the Development of the Porphyritic Texture in Igneous Rocks, Amer. Geol. 1900, Vol. XXV, pp. 299–310.

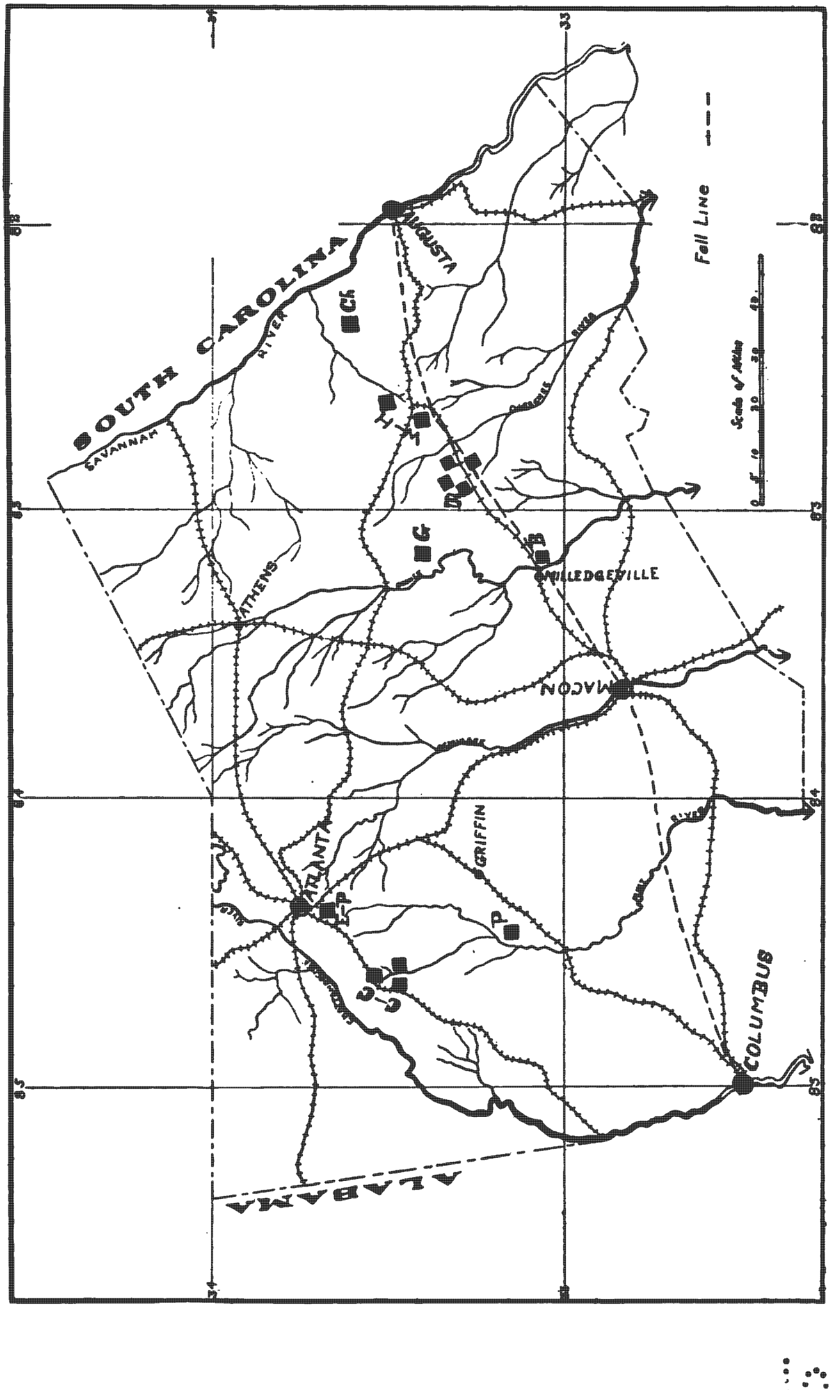


FIG. 1.—Map of Piedmont, Georgia, showing distribution of porphyritic granite described in the text.

The size, development and character of the phenocrysts in the porphyritic portions of the areas; and the gradation from one rock facies into another of the same composition shown in the same rock-mass, unquestionably point to contemporaneous growth with the groundmass constituents, and have, therefore, been formed *in place* and not at greater depths—intratelluric. In the present paper, it is proposed, therefore, to give a brief description and summary of the individual porphyritic granite areas; and to state the reasons for the belief in the contemporaneous origin of the phenocrysts with the groundmass constituents, based on a careful field and laboratory study of these rocks.

DESCRIPTION OF INDIVIDUAL AREAS

The Fayette-Campbell-Coweta counties porphyritic granite area.[1]—This area, marked C–C on the accompanying map, is thirty miles southwest from Atlanta and occupies contiguous portions of Campbell, Coweta and Fayette counties. The rock-outcrops are usually small and in the nature of bowlder and flat-surface masses. The exposures are most numerous in the vicinity of Palmetto and Coweta Stations on the Atlanta and West Point railroad, and near Line Creek in Fayette county. Specimens of the porphyritic rock collected from the outcrop near Line Creek in Fayette county are somewhat lighter in color than similar ones from the Palmetto-Coweta portions of the massif. The ratio of quartz to biotite in the Line Creek outcrop is visibly greater than in the Campbell-Coweta exposures, as indicated in analyses II and XI, p. 119. The rock, however, is generally quite uniform over the entire area. Several good contacts of the partially decayed porphyritic granite and mica-schist are exposed along the wagon roads and in the cuts of the railroad, traversing the area. The field relationships of the two rocks indicate, that the porphyritic granite is the younger rock; intruded into the overlying schist, and exposed subsequently by erosion.

The rock is a very coarse-grained porphyritic-biotite granite of a medium, light to dark gray in color, according to the amount of biotite present. The extreme coarseness of texture renders the porphyritic structure less typically marked in this than in finer grained porphyritic rocks. The porphyritically developed mineral (feldspar) grades imperceptibly from very large, irregular, sometimes stout, tabular phenocrysts, into the smaller feldspars, making it difficult usually to distinguish between groundmass and phenocryst feldspars, except in extreme cases.

---

[1] Eighteenth Annual Report, U. S. Geol. Surv., 1898, pp. 551–572.

The feldspar phenocrysts vary from extremely irregular cleavable grains, anhedra, 30 by 30^{mm} to roughly idiomorphic crystals; tabular, parallel to the clinopinacoid (010), and twinned according to the Carlsbad law. Abundant inclusions of large irregular plates of biotite are readily visible in all the phenocrysts to the unaided eye. The phenocrysts are prevailingly allotriomorphic in outline and differ in this respect from those of the other areas described below. The feldspars are white in color, usually partially cloudy or opaque rather than limpid in appearance.

The biotite occurs as stout cleavable plates averaging 10–15^{mm} in size, occupying somewhat well-defined areas; is very dark in color, and highly lustrous. The quartz is present in large irregular colorless and smoky anheda, 4–5^{mm} in size, clearly outlined against the feldspar and biotite, from which it is readily distinguished.

Microscopic study of thin sections of the porphyritic granite confirms the macroscopic description, in affording no marked differentiation between groundmass feldspar and a part of the similar porphyritic constituent, or phenocryst.

The feldspar constituent is composed of the potash varieties, orthoclase and microcline, and a fair proportion of an acid plagioclase, which from its optical properties is near oligoclase. The presence of considerable lime in the analysis tends to corroborate this inference. The orthoclase usually shows good cleavage, and is separately intergrown with stringers of albite and quartz, in the form of microperthitic and micropegmatitic structures. The potash feldspars and quartz of the groundmass are entirely allotriomorphic in crystal outline. The plagioclase feldspar occurs in roughly idiomorphic lath-shaped crystals characterized by the polysynthetic twinning, and, as a rule, afford very small extinction angles in basal sections.

The porphyritically developed minerals (phenocrysts) are composed of both orthoclase with numerous microperthitic structures, and microcline, usually inclosing inequidimensional anhedra of quartz, feldspar and biotite without definite optical orientation. The more basic inclusions, accessory apatite and zircon are also included in the phenocrysts.

A thin section of one of the feldspar phenocrysts from the Coweta portion of the area, shows the characteristic microcline structure, and contains abundant inclusions of irregularly bounded crystals of feldspar, quartz and biotite; several rounded disks or ovals of micropegmatitic intergrowths of quartz and feldspar, and prismatic needle-like inclusions of apatite and zircon (see Fig. 2.) A chemical analysis of fragments of carefully selected phenocrysts from hand specimens of the Coweta outcrops of the rock is given in XI a, page 119.

The biotite occurs as aggregated intergrown shreds with deep brown color, good basal cleavage and strong absorption, partially altered to chlorite and some epidote. The biotite is intergrown with occasional foils of muscovite, and sometimes shows good crystallographic boundaries. In addition to these, prismatic inclusions of apatite and zircon and a few grains of magnetite are present. The effects of dynamo-metamorphism are generally indicated to some degree in the rock by numerous fracture-lines and undulatory extinction common to the larger quartz and feldspar individuals.

Cubes[1] from the Rockingham, Richmond county, and Mt. Monroe, Iredell county, granite areas in North Carolina, very closely resemble in color, grain and texture the Campbell-Coweta-Fayette counties porphyritic granite, in Georgia. The phenocrysts in the Carolina rock are usually allotriomorphic, occasionally idiomorphic, in crystal outline; and, as a rule, are large in size, and contain numerous plates of included biotite. A similar though darker colored rock, owing to a greater amount of biotite present, occurs in Aiken county, South Carolina. The porphyritic feldspars in the Aiken rock present the same characteristics as the phenocrysts of the Georgia and North Carolina porphyritic granites.

---

[1] Through the kindness of Dr. George P. Merrill, Head Curator, Department of Geology, U. S. National Museum, the writer was accorded access to the Tenth Census Collections of Building Stones in the Museum.

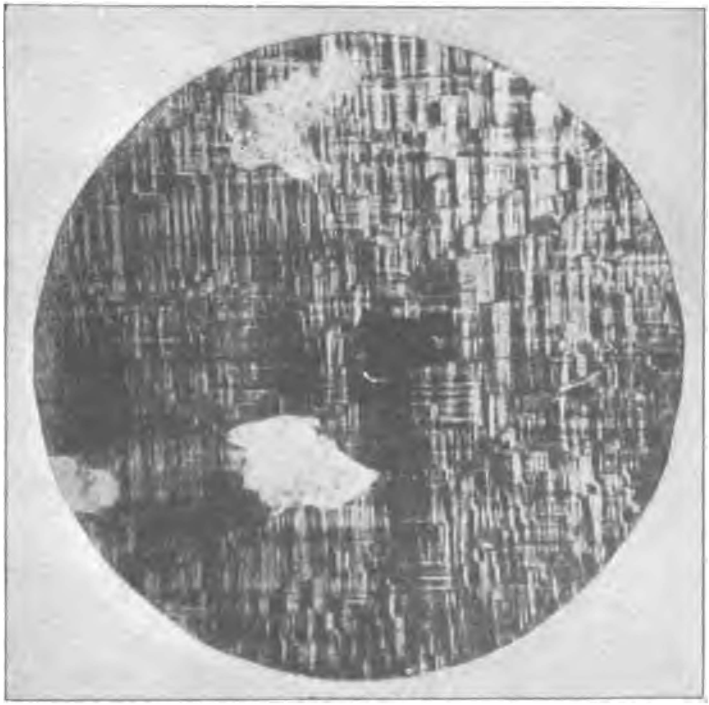


Fig. 2.—Photomicrograph of a phenocryst of microcline from the Coweta county porphyritic granite area, showing inclusions of quartz, plagioclase and biotite. The inclusions of plagioclase and biotite are considerably altered. Crossed nicols. Magnified 74 diameters.

The Hancock county porphyritic granite area.—A coarse-grained porphyritic granite outcrops one quarter of a mile east of Sparta depot, with the exposures more or less continuous from this point, for eleven miles, in a northeastwardly direction, along the Georgia railroad. The area lies near the merging of the crystalline rocks beneath the Coastal Plain sands and clays — the Fall-line (area marked S on the map). It is elliptical in shape with its longer diameter eleven miles in length, trending northeast-southwest. The granitic rock outcrops as bowlder and flat-surface masses, frequently containing four to five acres of exposed rock in one body.

The rock texture is prevailingly porphyritic, grading, in many cases, into a non-porphyritic, even-grained granite of the same mineral and chemical composition. In several quarries the rock shows in places a somewhat pronounced gneissoid structure. Some half dozen quarries have been extensively worked in various places over the area, within a few miles northeast of Sparta.

The rock is prevailingly a coarse-grained, medium gray, porphyritic biotite-granite. The phenocrysts are composed of the potash feldspars having a pronounced pinkish cast which disappears in thin section. They are flat tabular in crystal form, averaging 20^{mm} in length parallel to the clinopinacoid (010). Carlsbad twins of the contact type are common. The phenocrysts are further characterized by numerous inclusions of all the groundmass minerals.

The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, potash and soda-lime feldspars and biotite, with some accessory muscovite, chlorite, apatite, zircon, epidote and scattered grains of magnetite. Microperthitic structures are common to the potash feldspars. Micropegmatitic structures are less frequently observed, than in some of the other areas. The rock from the Sparta area differs from that of the Campbell-Coweta-Fayette counties area in containing less biotite, and hence, lighter in color; in the phenocrysts being idiomorphic instead of allotriomorphic in crystal outline, and usually of a pinkish cast rather than white in color. Microcline is, alike, variable for the two areas in thin sections of the rock examined from various places. The relative proportion of the component minerals is, including all species present, feldspar > quartz > biotite.

Like the former area, the Sparta porphyritic granite is surrounded on all sides by mica-schist; but the great depth of residual decay of the granite and schist, renders exposures of the contact between the two impossible. The field relationships however, indicate, as in the above area, that the granite is the younger rock, intrusive into the then overlying schist.

The Baldwin county porphyritic granite area.—Large bowlder outcrops of a coarse-grained porphyritic granite occur three miles southeast from Milledgeville, the county seat of Baldwin. Like the Sparta area, the Baldwin county porphyritic granite mass is located near the line of contact (Fall-line) between the Piedmont crystallines and the Coastal Plain sediments (area marked B on the map).

Hand specimens of the granite from Baldwin county are indistinguishable from similar specimens of the Columbia county porphyritic mass, described below. The rock is a very coarse-grained porphyritic granite, composed of an aggregate of interlocking quartz and feldspars—orthoclase with microperthitic structures, microcline and plagioclase—with intergrown shreds of biotite. The rock varies in color from medium to dark gray. Both microcline and orthoclase occur in the groundmass and as porphyritically developed minerals. The phenocrysts measure in extreme cases 30–40^{mm} long and 5–10^{mm} broad. They are prevailingly idiomorphic in form; flat, tabular parallel to the clinopinacoid (010), and commonly twinned according to the Carlsbad law. Abundant inclusions of black biotite foliae are plainly visible to the unaided eye in the feldspar phenocrysts; while the microscope shows additional numerous irregularly bounded quartz and feldspar grains without definite orientation.

The groundmass is composed of an abundance of white opaque feldspars, slightly dark-colored smoky quartz, and biotite plates measuring 2–5^{mm} in diameter. The microscopic accessories are primary inclusions of apatite and zircon and scattered grains of magnetite, with some secondary muscovite, chlorite and epidote derived from the alteration of the feldspars and biotite. Bent and curved filaments of rutile are quite abundant as inclusions in the larger quartz crystals. The effects of slight pressure metamorphism are evident in the lines of fracture and undulous extinction common to the larger quartz and feldspar individuals.

The Warren county porphyritic granite area.—Two somewhat extensive outcrops of foliated porphyritic granite occur in the middle eastern portion of Warren county, approximately ten miles from each other, in an almost east and west direction. These are known as the Holder's-Mill and Brinkley-Place granite masses, respectively, and marked W–H on the map.

The rock has a pronounced secondary foliated structure. The quartz and feldspar crystals are drawn out and inclosed between the biotite layers, forming at times distinct "augen" of the two light-colored minerals. The rock contains abundant black biotite plates arranged along somewhat parallel lines. The quartz and feldspar grains are greatly squeezed and mashed, and are more or less drawn out in directions parallel with the biotite layers, as a result of metamorphic action. The porphyritic granite of this area owes its foliated structure, therefore, to pressure metamorphism,[1] so common to many igneous rock masses in those regions subjected to mountain-building forces. Hence it is derived or secondary and not primary or fluidal.

The feldspar phenocrysts are composed principally of microperthitic orthoclase with some microcline 15–20^{mm} long; are white opaque to pink in color; contain numerous inclusions of biotite plates, and exhibit the usual habit of Carlsbad twins. They are prevailingly irregular in crystal outline and badly fractured from subsequent intense metamorphism. The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, feldspar and biotite. The groundmass feldspathic constituent consists of the potash feldspars with microperthitic structures, and some laths of plagioclase near oligoclase. The large feldspar individuals (phenocrysts) contain inclusions of irregularly bounded crystals of quartz, biotite and other feldspar species. These inclusions are usually round, oval shape in outline. The quartz and feldspar anhedra are variously interlocked as fine and coarse-grained mosaics. The finer-grained mosaics of the two minerals represent the peripheral shattered portions of the larger feldspar and quartz crystals. Micropegmatitic structures, intergrowths of quartz and feldspar, are very common. Biotite occurs as grouped shreds and plates, deep brown to occasional green in color, with strong absorption and good basal cleavage. It is partially altered to a dark opaque chlorite and occasional crystals of slightly pleochroic and strongly double refracting epidote. A few scattered grains of magnetite are observed.

---

[1] Gregory has established, according to origin, three classes of gneisses, namely, metapyrigen-gneisses, clastic-gneisses, and fluxion-gneisses. See Quart. Jour. Geol. Soc. (London), 1894, p, 266; DALY, R. A. JOUR. GEOL. (Chicago), Vol. V, p. 780.

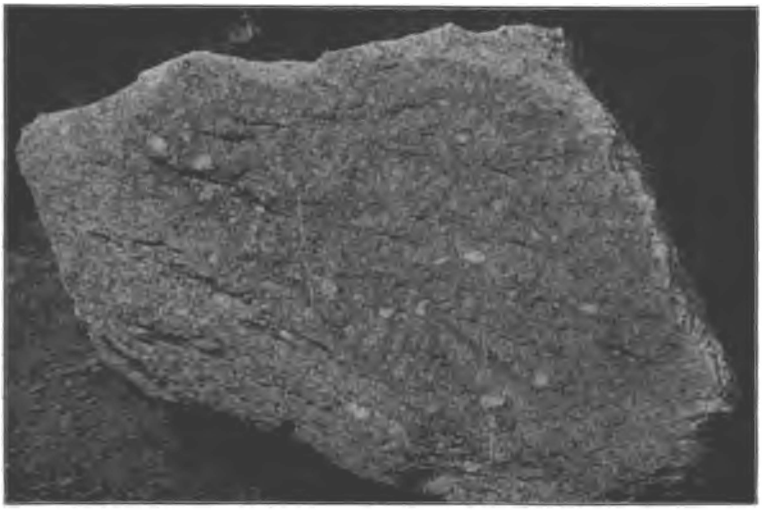


FIG. 3.—The Virginia type of foliated porphyritic granite near Chatham, Va.

An outcrop, from which some rock has been quarried, of a similar dark-colored, foliated biotite porphyritic granite is found near Chatham depot, Pittsylvania county, Virginia. The feldspar phenocrysts are very large in size, 40–50^{mm} long, roughly tabular in outline and twinned according to the Carlsbad law, and shows an abundance of large included biotite shreds (see Fig. 3).

Still a third exposure of granitoid rock showing a pronounced porphyritic texture in places, occurs six to eight miles south of the Holder's Mill-Brinkley Place area. It differs quite strongly from the Holder's Mill-Brinkley Place granite in the porphyritic texture being less strongly marked and finer grained; in containing less biotite, and is massive instead of foliated in structure. It further differs from the former area in containing a larger proportion of plagioclase, and a smaller percentage of microcline feldspars. Only one included grain of microcline was found in a number of thin sections studied of this rock. The feldspar phenocrysts are deep pink in color, 5–10^{mm} long, displaying the usual characteristic twinning and cleavage; and carry numerous inclusions of all the groundmass minerals.

The Greene county porphyritic granite area.—The Greene county porphyritic granite area, marked G on the accompanying map, includes at least 100 acres in the main granite outcrop, located ten miles south of Greensboro, in the southern part of the county. The main central exposure is in the form of a low flat doming-mass with a roughened and irregular surface, and partially covered, in places, with a thick growth of cedars (see Fig. 4).

An even granular medium coarse-grained granite outcrops in bowlder form three miles south of Greensboro, and is continuous along the public highway from this point to the main porphyritic granite mass (see Fig. 5). The true granitic facies of the rock mass grades interiorly into the typical porphyritic granite facies. The even-grained granitic portion of the mass representing the outer or peripheral zone, indicates some variation in mineral composition, from place to place, along a north and south section. The zone nearest the porphyritic area, two and one half miles north therefrom, and showing absence of all trace of porphyritic texture, is a medium-grained biotite granite agreeing, microscopically, in mineral composition, and in chemical composition as well, with the porphyritic granite.

Five miles north of the central porphyritic mass are outcrops of a coarse but close compact-grained granite, containing only a very small amount of biotite. The feldspars show pronounced pink and greenish tints.

About four miles south of Greensboro, on the north side of Beaver-Dam Creek, is an outcrop of practically the same granite. The quartz is decidedly dark in color and of the smoky variety; the feldspars are flesh colored, and the rock contains but little mica.

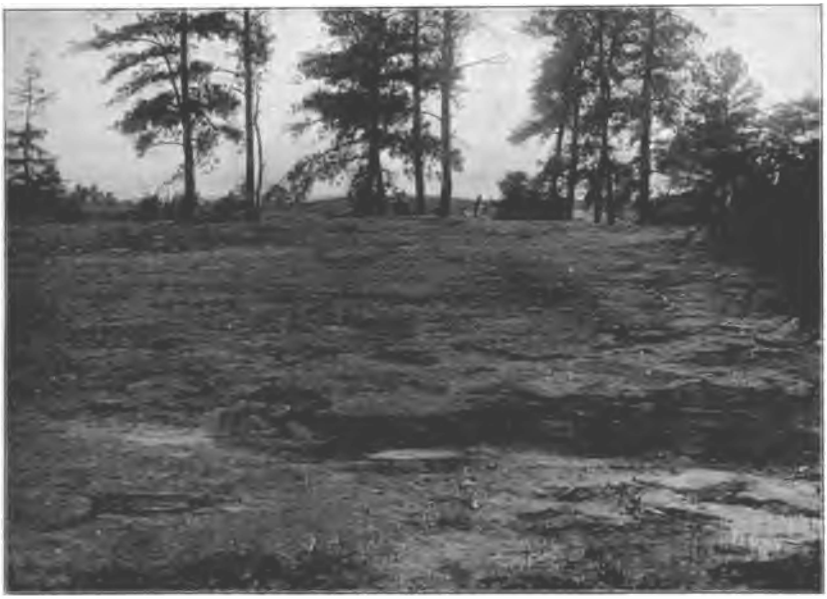


FIG. 4.—The Greene county porphyritic granite area.

The porphyritic facies of the rock consists of a coarse-grained, light-gray groundmass of quartz, feldspar and biotite, in which are embedded large, flat tabular feldspar phenocrysts. The porphyritic feldspars average 30–50^{mm} long and 10–15^{mm} broad; and indicate the usual elongation parallel to the clinopinacoid (010), and Carlsbad twinning. The phenocrysts are deep pink to perfectly white in color, and are usually cloudy and opaque in appearance.

A thin section of one of the phenocrysts under the microscope showed the feldspar variety, microperthitic orthoclase. The microscope further showed abundant inclusions of fairly large crystals of feldspar, twinned, in several cases, after the albite and Carlsbad laws; and allotriomorphic crystals of quartz and biotite with partial orientation with the (010) cleavage.

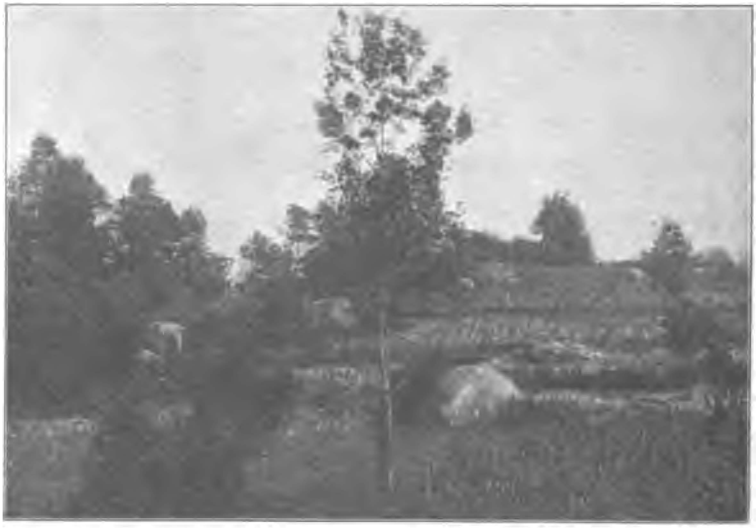


FIG. 5.—Bowlder outcrops of granite near central mass of the Greene county porphyritic granite area.

(Fig. 6.) As a rule, however, the inclusions show no definite orientation. The biotite inclusions are always sufficiently large to be visible to the unaided eye.

The ratio of phenocryst to groundmass is quite variable; the probable extremes being represented by the following estimated ratios; 1 : 1 and 2 : 1, with all gradations between. The individual mineral grains vary from a few millimeters to 5 and 6^{mm} in size. The arrangement of phenocrysts in occasional small portions of the mass is suggestive of fluxion structure.

The potash feldspars, orthoclase and microcline, are the porphyritically developed minerals. The orthoclase contains numerous microperthitic structures. Plagioclase is somewhat abundant. Small-rounded disks or ovals of micropegmatitic structures are common. The larger feldspar and quartz crystals indicate slight peripheral shattering in some of the thin sections.

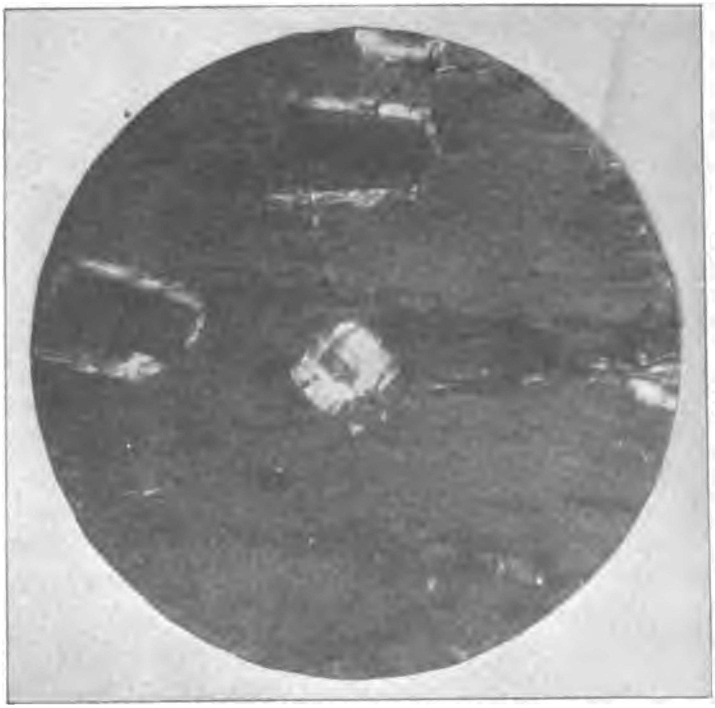


FIG. 6.—Photomicrograph of a phenocryst of microperthitic orthoclase from the Greene county porphyritic granite area, showing inclusions of quartz, plagioclase, biotite, and very small prisms of apatite. Crossed nicols. Magnified 74 diameters.

The biotite is considerably altered to chlorite and some epidote, and at times carries inclusions. Scattered grains of magnetite and prismatic inclusions of apatite and zircon are present in microscopic proportions.

The Columbia county porphyritic granite area—Heggie Rock.— This area, marked Ch on the accompanying map, is located near the Fall-line—contact between the Piedmont crystallines and the Coastal Plain sediments—and a short distance west of the Carolina line.

One and three quarter miles east of Appling, the county seat of Columbia, is an outcrop of a coarse-grained porphyritic granite. The feldspars are slightly pink in color with a somewhat greenish cast in places. The phenocrysts measure 20–35^{mm} in length and 5–15^{mm} broad; and commonly show the contact type of Carlsbad twins.

Microscopically, the rock is composed of a coarse-grained groundmass of potash and plagioclase feldspars, orthoclase predominating, and quartz with biotite and occasional large plates of muscovite. The phenocrysts are large tabular microperthitic orthoclases. The anhedra of quartz vary in size and are badly fractured. Laths of polysynthetically twinned plagioclase are more abundant in this than in many of the other areas. Pegmatitic intergrowths of quartz and feldspar are sparingly present. The large feldspar phenocrysts contain abundant inclusions of the groundmass minerals, especially biotite and plagioclase.

The main porphyritic granite mass is one and one quarter miles further east. The rock outcrops as a large doming-mass. The porphyritic facies of the granite-mass is readily traceable peripherally into an even granular medium coarse-textured granite. The even granular facies of the rock mass is best exposed along the public highway three miles slightly east of south from Appling. Hand specimens of the rock from the two exposures cannot be distinguished from each other. The porphyritic feldspars in the principal exposure are larger but show the same idiomorphic and other microscopic tendencies, developed in the smaller one.

A thin section of one of the phenocrysts from the main outcrop showed the characteristic microcline structure, with numerous inclusions of irregularly bounded crystals of all the groundmass minerals. A chemical analysis of carefully selected fragments of phenocrysts from this rock, yielded the writer the results given in IVa, page 119.

The phenocrysts are embedded in a close and firm, but coarse-grained groundmass of flesh-colored feldspars tinged a slight greenish cast, somewhat dark smoky quartz, and biotite. The porphyritic feldspar crystals make up nearly one half of the total rock. The feldspars are white and opaque rather than pink in color over the greater part of the exposure. This rock very closely resembles that from Greene county in the hand specimens. Here, as in the areas described above, the feldspathic constituent consists of the potash and soda-lime feldspars, with the potash varieties predominating. The porphyritic feldspars are chiefly orthoclase with some microcline, carrying inclusions of all the groundmass minerals. The included biotite shreds are visible macroscopically. Some of the largest plagioclase inclusions in the orthoclase phenocrysts carry, in turn, microscopic inclusions of quartz and other groundmass minerals. Twinning according to the Carlsbad and albite laws among the included feldspar species is commonly observed.

Biotite shows its usual characteristic optical properties, and is partially altered to chlorite and epidote. Muscovite is sparingly present as foils intergrown with the biotite. Sporadic accessory magnetite and apatite occur.

The Pike county granite area.—The Pike county granite area, marked P on the accompanying map, includes fifty or more acres of exposed flat-surface rock in the northwest part of the county. The porphyritic facies of the rock gradually passes into the even-textured medium-grained granite. Only a small proportion of this area, however, shows the porphyritic texture.

The rock is a medium-grained biotite granite, varying from even granular to porphyritic in texture, showing a partial gneissoid structure in places.

Microscopically, the porphyritic portions of the rock are composed of orthoclase phenocrysts in a coarse-grained groundmass of quartz, microperthitic orthoclase, microcline and some soda-lime feldspar, biotite, and occasional intergrown shreds of muscovite. Biotite is the chief accessory mineral. It is deep brown to yellow in color, with strong absorption, and is intergrown with some muscovite. It is more or less altered to dark green opaque chlorite, and to a less degree, to a faint brown pleochroic epidote. Inclusions of prismatic apatite and zircon, and rounded disks or ovals of micropegmatitic structures are very common.

The phenocrysts consist of the potash feldspars, orthoclase and microcline, 10–30^{mm} long and 5–10^{mm} broad; tabular parallel to the clinopinacoid (010). Carlsbad twinning is common. Inclusions of biotite foliae equally as large as those occurring in the groundmass are very abundant in the phenocrysts. In addition to the biotite, they contain microscopic inclusions of irregularly bounded crystals of the interstitial quartz and feldspar.

The Fulton county porphyritic granite area.—The Fulton county porphyritic granite area, marked E–P on the accompanying map, is exposed in bowlder form over a large territory six miles south of Atlanta, in the extreme southern part of the county. The gradation from the interior porphyritic facies, peripherally, into an even-grained granite of the same color and texture, and having the same mineral and chemical composition, is more gradual and more strikingly shown in this than in any one of the previously described areas. Near the center of the granite mass the phenocrysts compose more than 50 per cent. of the entire rock, while near the transition zone—change of the porphyritic to the non-porphyritic texture—the phenocrysts are very sparingly present, not more than a half dozen are shown in a yard square of the rock surface. Near the center, the phenocrysts are prevailingly idiomorphic in crystal outline, while the allotriomorphic type of phenocryst characterizes the transition zone of the rock mass.

The rock consists of a medium coarse-grained groundmass of quartz, the potash feldspars, orthoclase and microcline, numerous laths of polysynthetically twinned plagioclase, biotite, and some muscovite, in which are embedded large potash feldspar phenocrysts. Accessory apatite, magnetite, and zircon; and the alteration products, muscovite, sericite, chlorite, and kaolin are noted. The microscope shows the feldspars and biotite to be considerably altered in some cases.

Microcline and orthoclase occur porphyritically developed, and measure 15 to 50^{mm} in length. The phenocrysts possessing idiomorphism usually display the Carlsbad habit of twinning, and are elongated in the clinopinacoidal direction.

A thin section of one of the phenocrysts showed the characteristic microcline structure and numerous inclusions of quartz, biotite, and the groundmass feldspars, which measure as much as one millimeter in size. Prismatic crystals of apatite and zircon, as inclusions in both the phenocryst and the included groundmass feldspars of the porphyritic crystal, are numerous. The zircon crystals are sometimes grouped in threes, much after the manner of penetration twins.

RÉSUMÉ

Since the individual areas have been described in some detail, it is important that a general summary of the essential features common to the several porphyritic granite masses be given. These can best be summarized under the two headings, *macro-* and *microscopic* features.

Macroscopic features.—The same textural and structural characteristics and relationships are generally developed in all the individual porphyritic granite areas. With the exception of the Warren (W–H) county area, the rocks are prevailingly massive, coarse-grained, porphyritic granites, varying, according to the proportion of biotite present, from dark to medium gray in color. The Warren county granite differs structurally from that of the other areas in possessing a marked foliated structure, resulting from dynamic metamorphism, which is accordingly secondary. Further evidence already mentioned of dynamic action in this rock mass is apparent microscopically. Evidence of a partial gneissoid structure is indicated in portions of several of the other areas, but, as a rule, the rock is generally massive.

Field study shows the development of the porphyritic texture in the interior of the rock masses, with the even-granular granitic facies having the same mineral and chemical composition forming the marginal or body portion. Gradation from one rock facies into the other was not entirely clearly defined in all of the granite masses, owing to lack of exposures of the fresh rock, but could be easily traced in many. The feldspar phenocrysts are irregularly distributed through the coarse-grained groundmass without definite arrangement or orientation. The fluxion primary structure was not entirely evident in any one of the areas studied.

Microscopic features.—Microscopically, the rocks are as nearly identical as is possible for separate areas to be. They contain, in every case, the same minerals, both essential and accessory, in nearly the same proportions. They are composed of admixtures of the feldspars and quartz, in which lie stout plates of biotite. The relative amounts of the component minerals may be expressed as follows: feldspar, including all species present, >quartz>biotite. Biotite is the chief accessory and varies somewhat in quantity for the individual areas. In a number of the sections the biotite is intergrown with occasional foils of muscovite. The potash feldspar varieties of the groundmass predominate and are prevailingly allotriomorphic in crystal outline. Both orthoclase and microcline occur with the former in excess. The plagioclase crystals are roughly lath-shaped in outline, and, as a rule, afford small extinction angles in basal sections, which indicates an acid feldspar near oligoclase. The presence of considerable lime and soda in the analyses corroborates the inference. The orthoclase feldspar shows microperthitic intergrowths with a second feldspar, probably albite. In all the sections some of the feldspar crystals show a micropegmatitic intergrowth with quartz, which takes the form of rounded disks or ovals, and are not of the arborescent or radiate growth type.[1] There can be little doubt that this structure is primary in the porphyritic granites as a whole, affording evidence of simultaneous crystallization of the quartz and feldspar. The quartz occurs in irregular interstitial grains of varying size, and is very common in drop-like inclusions in the feldspars. Prismatic inclusions of apatite are the most common of the primary accessories. Some zircon and a very little magnetite occur. More or less chlorite, some epidote and muscovite are present as constant secondary products from the alteration of the biotite and feldspars. In many of the sections, the effects of pressure metamorphism are frequent in the nature of crushing, lines of fracture, and undulatory extinction common to some of the larger quartz and feldspar crystals.

---

[1] See ROMBERG in N. J. B. B.—B., 1892, Vol. VIII. MATHEWS, E. B.: JOUR. GEOL., 1900, Vol. VIII, p. 231.

The potash feldspars are the only porphyritically developed minerals. The phenocrysts vary from allotriomorphic to flat tabular idiomorphic crystals in outline, in which the (001) and (010) cleavages are usually well developed, and are elongated in the clinopinacoidal direction. The usual habit of the simple Carlsbad twins prevails. The idiomorphic type of phenocryst greatly predominates over the allotriomorphic form. As a rule, the phenocrysts are very conspicuous, and are readily differentiated from the groundmass feldspars; although in the Coweta-Campbell-Fayette counties area (C–C) the phenocrysts and a portion of the groundmass feldspars seemingly grade into each other. The phenocrysts invariably contain inclusions of a majority of the groundmass constituents, some of which are visible to the unaided eye. The inclusions are distributed, as a rule, through the rock without regard to any definite arrangement or orientation.

CHEMICAL COMPOSITION

The marked uniformity in the mineral composition of the various porphyritic granites from the individual areas, suggests similar uniformity in chemical composition. The usual amount of free quartz common to this class of rocks; the abundance of potash feldspar, with somewhat increased amounts of plagioclase and proportionally small amounts of accessory minerals, indicate a normal percentage of silica and lime, an increased percentage of alkalies, and comparatively small amounts of iron and magnesium oxides. These inferences are well shown in the following analyses, made by the writer, in the laboratory of the State Survey. Attention is called in the table of analyses to the prevailingly high percentage of soda in all of the rocks described above. In nearly half of the analyses, the soda is slightly in excess of the potash, and in the remaining ones it nearly equals or is but slightly less than the potash. This high range in soda is traceable, first, to the prevalence of microperthitic intergrowths of albite with the potash feldspars; next, to the amount of soda-lime feldspar present in the rocks; and, lastly, to the potash being replaced, in part, by soda in the straight potash feldspar molecule (analyses IVa and XIa).

GENETIC RELATIONSHIP OF PHENOCRYST TO GROUNDMASS

Evidences of intratelluric origin.—The evidences upon which the formation of phenocrysts at great depths and under conditions different from those of the groundmass constituents in igneous, intrusive rocks, rest have been adequately discussed by Pirsson[1] and are shown to be: (1) Contrast in size and crystal form of phenocryst to the groundmass constituents. (2) The fluidal arrangement, common in many cases, to the porphyritic minerals. (3) Irregularity of form, traceable to corrosion or resorption of the crystal (phenocryst) by the magma.[2]

These will be discussed in relation to the phenocrysts of the Georgia porphyritic granites under the next heading.

Evidences of contemporaneous origin.—The evidences favoring contemporaneous origin of the phenocrysts in the Georgia porphyritic granites may, for convenience, be discussed under (1) megascopic proofs: geologic or field observations; and (2) microscopic proofs: study of the thin sections of the rocks.

Both the macro- and microscopic characteristics of the Georgia porphyritic granites have been described in considerable detail under the individual areas above. Hence it is only necessary here to summarize and classify the facts pointing to a contemporaneous origin for the phenocrysts.

---

[1] Amer. Journ. Sci., 1899, Vol. VII, p. 278.

[2] IDDINGS, J. P.: Bulletin, Phil. Soc. of Washington, 1889, Vol. XI, p. 77.

TABLE OF CHEMICAL ANALYSES

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	IVa	XIa
SiO_2	70.90 1.181	70.88 1.181	70.24 1.170	69.77 1.162	69.48 1.158	69.37 1.157	69.17 1.152	69.13 1.152	67 62 1.127	66.31 1.105	63.65 1.060	64.64	64.40
Al_2O_3	15.86 .155	15.86 .155	16.78 .164	17.05 .167	16.64 .163	16.99 .166	16.47 .163	17.14 .168	16.29 .159	18.27 .179	20.46 .200	19 64	18.97
Fe_2O_3*	1.37 .008	1.77 .011	1.46 .009	1.60 .010	1.84 .011	1.99 .012	1.23 .007	1.52 .009	2.31 .014	2.51 .015	2.20 .013	0.37	0.37
CaO	2.15 .038	1.79 .032	2.00 .035	2.21 .039	2.32 .041	2.03 .036	2.02 .036	1.85 .033	2.37 .042	2.91 .052	3.28 .058	0.67	0.59
MgO	0.02 .001	0.93 .023	0.76 .019	0.99 .024	0.29 .007	0.84 .021	0.61 .015	0.79 .019	0.78 .019	1.22 .030	1.50 .037	tr.	tr.
K_2O	4.62 .049	4.64 .049	5.03 .053	4.08 .043	4.49 .047	4.54 .048	4.41 .047	5.49 .058	4.58 .048	4.09 .043	4.58 .048	10.00	11.40
Na_2O	5.05 .081	3.94 .063	3.70 .059	3.97 .064	4.74 .076	3.44 .055	4.89 .078	4.06 .065	5.42 .090	3.69 .059	4.75 .076	3.06	3.60
Igni	0.50	0.49	0.50	0.44	0.46	0.55	1.06	0.52	0.32	0.62	0.42	0.22	0.19
Total.....	100.47	100.30	100.47	100.11	100.26	99.75	99.85	100.50	99.69	99.61	100.84	98.60	99.52

* All iron was determined as Fe_2O_3.

I. Georgia Quincy Granite Company's Quarry, near Sparta, Hancock county.
II. A. J. McElwaney's place, near Line Creek, Fayette county.
III. Flat (Cedar) Rock, 9 miles west of Zebulon, Pike county.
IV. Heggie-Rock, 3 miles east of Appling, Columbia county.
V. Sparta Quarry, Hancock county,
VI. Mrs. L. N. Calloway's place, 3 miles southeast from Milledgeville, Baldwin county.
VII. The Moseley Quarry, 6 miles south of Atlanta, Fulton county.
VIII. Porphyritic granite area, 10 miles south of Greensboro, Greene county.
IX. The Charley Rocker Quarry, near Sparta, Hancock county.
X. Brinkley place, near Camak, Warren county.
XI. The J. R. McCollum place, near Coweta Station, Coweta county.
IVa. Feldspar phenocrysts from Heggie-Rock, Coumbia county.
XIa. Feldspar phenocrysts from the J. R. McCollum place, Coweta county.

The field observations include (1) passage or gradation interiorly from the porphyritic facies, peripherally into an even-granular, coarse-textured granite of the same mineral and chemical composition. The peripheral or border zones of the porphyritic granite masses, representing the granular facies of the rock, generally attain considerable widths in the Georgia areas, from which phenocrysts are entirely absent. (2) The general absence of definite (fluidal) arrangement or orientation of the phenocrysts in the groundmass. The Greene county porphyritic granite mass possibly affords, in places, the faintest possible evidence of the tabular phenocrysts having moved in a liquid magma, with partial definite arrangement or orientation. If these special parts of the area be accepted as indicative of flow structure, however, then we must also grant the contemporaneity in crystallization of the groundmass constituents for the same portions of the mass; for all of the other constituents, particularly biotite, are abundantly included in the phenocrysts of all parts of the area. The included biotite plates are equally as large as the same constituent in the groundmass. The other inclusions are microscopic in size and proportions.

The Brinkley-Place Holder's-Mill porphyritic granite has a pronounced foliated structure. This structure resembles in certain particulars, in places, the fluxion structure of some rocks, but in this case the foliation is shown to be secondary or derived — induced — and not primary or fluidal.

The phenocrysts are badly fractured and drawn out as "augen" between the inclosing groundmass minerals, roughly parallel in the direction of their longer diameters. Furthermore, the microscope indicates abundant squeezing and mashing and peripheral shattering of the quartz and feldspars, so characteristic of a secondary structure resulting from dynamometamorphism.

The microscopic evidence, favoring contemporaneous origin of the phenocrysts with the groundmass constituents, is chiefly that of prevailing abundance of all the groundmass minerals, as inclusions in the phenocrysts, for the areas studied. In every case the biotite inclusions are readily distinguished megascopically.

The comparative abundance of inclusions[1] in the phenocrysts, and the form and size of the latter, suggest a rapid growth for the porphyritic crystals. The inclusions are not limited to and distributed through the outer zones of the phenocrysts, indicative of different periods in crystal growth with reference to the groundmass constituents, but, on the contrary, they are scattered through all parts of the crystal (phenocryst). The inclusions are grouped, with few exceptions, without regard to crystallographic lines or directions, and without uniform orientation with reference to the host and each other. No external evidence in the nature of crowding and pushing aside of the adjacent groundmass microlites during the growth and expansion of the phenocrysts has been observed, resulting in some cases, as mentioned by Pirsson,[2] in the resemblance to the flow structure.

The microscope, as a rule, fails to indicate, in the rock sections studied, rounding or irregularity in crystal outline of the original phenocryst resulting from a partial resorption or corrosion of the crystals by the magma in the Georgia areas.

Phenocrysts of roughly idiomorphic outlines — flat, tubular- and irregular-allotriomorphic forms — appear, with the former predominating in most of the areas. In view of confirmatory evidence, elsewhere stated in this paper, idiomorphism among the phenocrysts in the Georgia rocks could in no-wise be accepted as resulting from formation at greater depths and under entirely different conditions from the other constituents. In the absence of all other evidence it would be difficult to prove that form alone was a definite criterion favoring intratelluric origin. Pirsson[3] has shown that contrast in crystal form and size may very well be explained in an entirely different way.

---

[1] *Ibid.*, p. 80. [2] Op. cit., pp. 276, 277.

[3] *Ibid.*, pp. 278–280; see also CROSBY, W. O.: Amer. Geol., 1900, Vol. XXV, pp. 299–310.

The absence of (*a*) definite arrangement or orientation among the phenocrysts; (*b*) of phenocrysts from the border zones of the massif—gradation from an interior porphyritic facies peripherally into an even-granular granite of coarse texture and the same mineral and chemical composition; (*c*) the further absence of evidence of magmatic resorption or corrosion of the phenocrysts; and (*d*) the presence of abundant inclusions of all the groundmass constituents, characterizing the generally tabular phenocrysts of the Georgia porphyritic granites, fully justify the conclusion that the phenocrysts in these rocks were formed *in place*, and are not intratelluric in origin.

THOMAS L. WATSON.

LABORATORY OF THE GEOLOGICAL
SURVEY OF GEORGIA,
Atlanta, Ga.

CERTAIN PECULIAR ESKERS AND ESKER LAKES OF NORTHEASTERN INDIANA

NORTHEASTERN Indiana is traversed by a series of massive moraines of late Wisconsin age, the joint product of the Erie and Saginaw lobes of the Laurentide ice-sheet. The Erie ice invaded the region from the south of east, the Saginaw ice from the east of north. Thus the general directions of ice movement in the two were at right angles to each other. The Saginaw lobe was relatively feeble and withdrew from the region before the Erie lobe. Along their line of contact there is much confusion, but it is possible to correlate the moraines and to mark out with considerable accuracy the limits of Erie and Saginaw drift.[1] The region abounds in unusual features. Half-filled valleys and abnormal drainage lines, isolated knobs and morainic outliers, clusters and chains of lakes, kettles, and kames conspire with esker-like ridges to produce a type of topography and scenery which seems artificial and almost bizarre. The southwestern portion of Noble county presents forms which are, perhaps, best described under the name of eskers.[2]

On the line between the townships of Noble and Washington a system of ridges occupies about two square miles and surrounds the basin of High Lake. The most prominent member is a gravel ridge one mile long, extending east and west along the south side of High Lake. It is highest and broadest at the east end, where it surrounds and encloses an oval kettle whose bottom is at lake level. The sides of the kettle rise to 25 and 35 feet at the lowest points, and to 70 and 85 feet at the highest points, which are at the ends of the oval. The westward extension of the ridge has a height varying mostly between 50

---

[1] Eighteenth Report Indiana Geology, pp. 28, 84.

[2] The data for the maps, Figs. 1 and 2, were obtained with an aneroid and tape line, township, section, and farm lines, and the surface of the principal lake in each being used as bases.

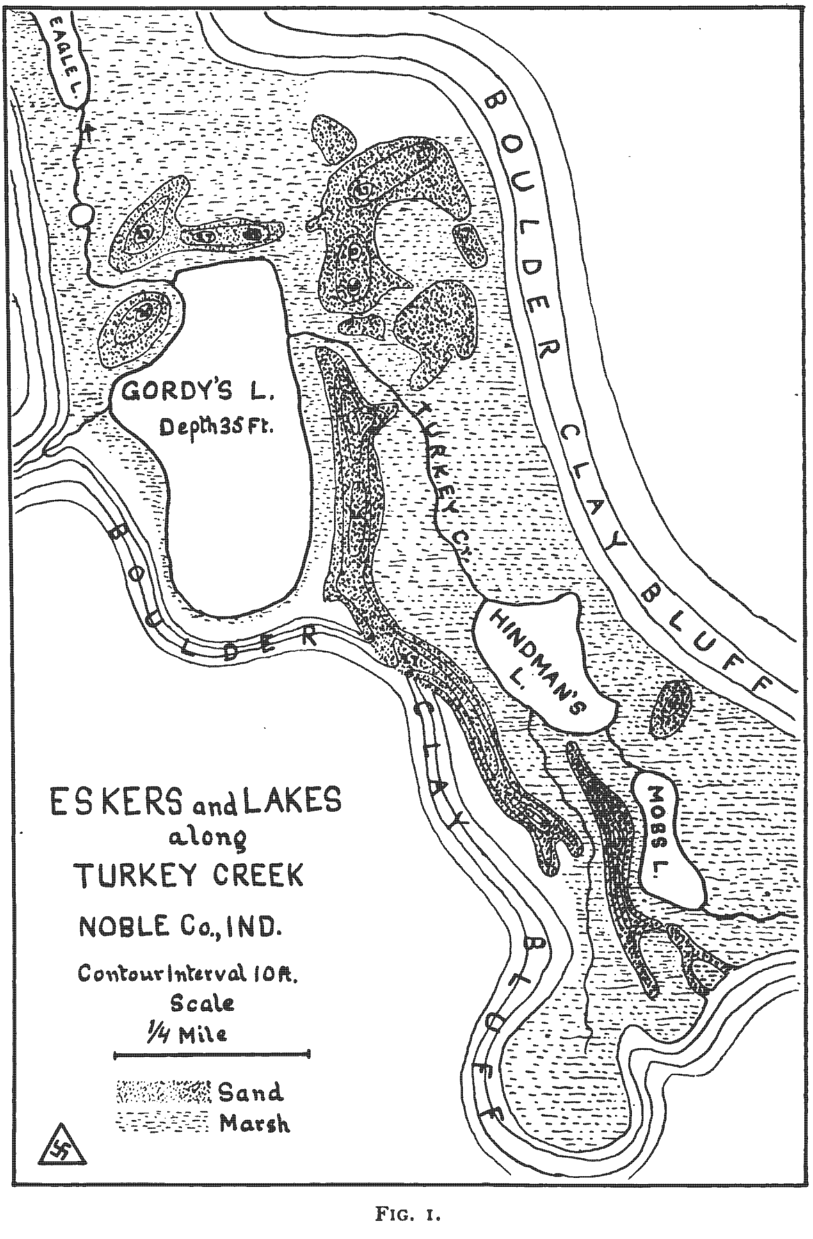

EAGLE L.
BOULDER CLAY BLUFF
GORDY'S L.
Depth 35 Ft.
TURKEY CR.
HINDMAN'S L.
MOSS L.
BOULDER CLAY BLUFF
ESKERS and LAKES
along
TURKEY CREEK
NOBLE Co., IND.
Contour Interval 10 ft.
Scale
1/4 Mile
Sand
Marsh

FIG. 1.

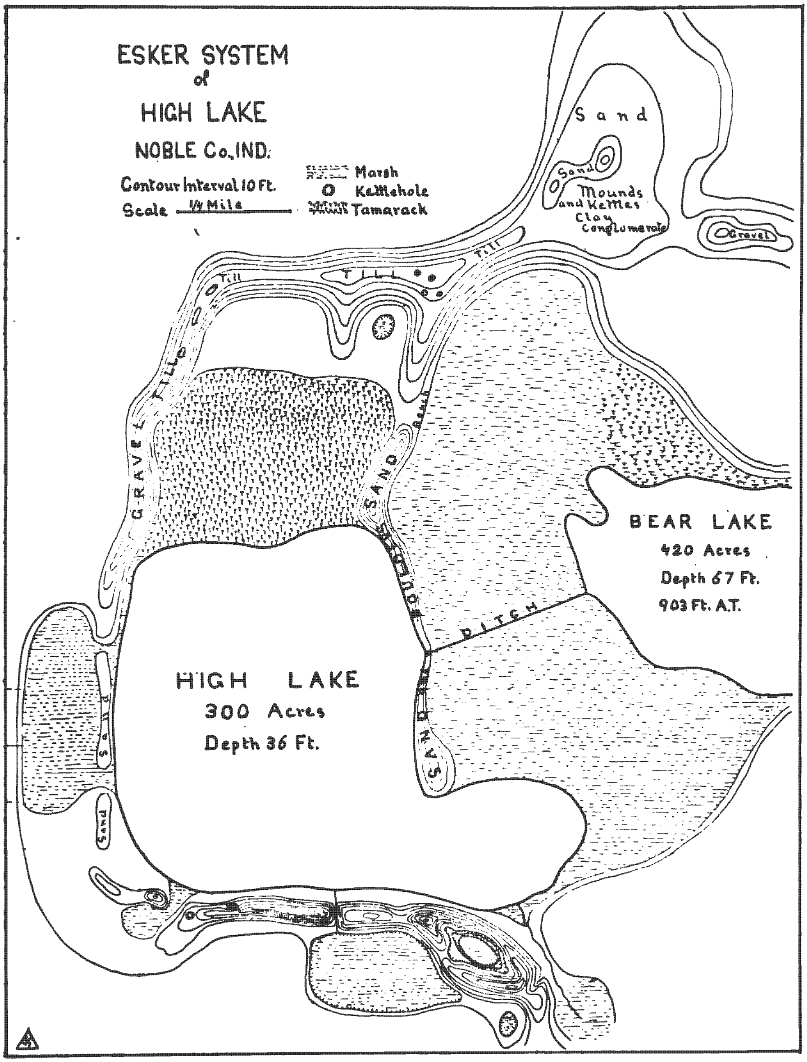

ESKER SYSTEM
of
HIGH LAKE
NOBLE Co., IND.
Contour Interval 10 Ft.
Scale 1/4 Mile
Marsh
Kettlehole
Tamarack
Sand
Sand
Mounds
and Kettles
Clay
Conglomerate
Gravel
Till
TILL
Till
GRAVEL TILL
SAND
Beach
BOULDERS
DITCH
BEAR LAKE
420 Acres
Depth 67 Ft.
903 Ft. A.T.
HIGH LAKE
300 Acres
Depth 36 Ft.
Sand
Sand
SAND

FIG. 2.

and 75 feet, falling to 30 feet at one point where a ditch has been cut through it. The crest is usually sharp, and the lateral slopes are as steep as the material will permit. A small pit which has been opened on the southeast slope shows coarse rounded gravel without definite stratification. The ditch is cut through sand and fine gravel. At one point near the lake shore there is an outcrop of cemented gravel. These are the only exposures, and since the whole ridge is covered by a heavy growth of oak timber, investigation is difficult.

A mile and a half to the north the gravel ridge just described is paralleled by an equally massive ridge of till which rises 50 to 60 feet above lake level and 30 to 40 feet above the general level of the country. It is broad and flat-topped with steep and symmetrical slopes, and pitted with numerous small kettles. It extends westward three fourths of a mile and then, bending sharply to the west of south, is prolonged an equal distance in that direction to the northwest corner of High Lake. The southern half of this portion, however, is composed of gravel; the transition from till to gravel being abrupt and marked only by a slight change in the trend. The gap between the ends of the two gravel ridges above described is almost closed by a series of broken ridges of sand, generally less than ten feet high, but rising in one sharp peak to forty feet.

From the central mass of the till-ridge two short spurs project toward the south. One of these is separated by only a small gap from a ridge of sand which continues in the same direction to the northeast corner of High Lake and along its eastern border. On the north it is broad, rounded, and 40 feet high, but narrows and falls toward the south to a height of 5 feet, then widens and rises to 35 feet at the southern end. The lowest part of this ridge is a pile of angular bowlders up to a foot in diameter, with the interstices filled with sand.

The till-ridge is prolonged a mile or more to the northeast by a broad elevation of complex structure and topography. The greater portion of its mass seems to be composed of sand, which forms the highest peaks, 65 and 70 feet above lake level. An area of at least twenty-five acres is studded with mounds and kettles, averaging about one each to the acre. One of these mounds has been excavated, and is shown to be made up of a uniform mixture of two thirds coarse gravel and one third clay. The clay forms a tough cement which holds up the material in a perpendicular face. The mixture might be called a clay conglomerate. A few large boulders occur in this tract. It is continued on the east by an isolated gravel mound rising to 65 feet above lake level.

The system of ridges forms an irregular parallelogram which nearly encloses the basin of High Lake. The northern part of the basin is occupied by a tamarack swamp. The area of open water is about half a square mile, mostly from 10 to 35 feet deep. It is deepest toward the south and west shores. There are no inlets except ditches from a few insignificant marshes, and in summer evaporation equals or exceeds supply. The overflow is by a small ditch to Bear Lake. The basins of the two lakes are really continuous, being only partially separated by the sand and boulder ridge. That their waters were once united is shown by a well-developed beach which borders the ridge and fills the gap between it and the till-spur.

This peculiar grouping of diverse and strongly marked features forms a puzzle difficult of solution. The east-west gravel ridge presents the characters of a subglacial esker, yet its height, steepness of slope, short extent and isolation are unusal. The presence of the great kettle hole piercing its center from top to bottom is not the least remarkable feature and contributes to the general impression of unnaturalness. The north-south ridges are sufficiently esker-like, but the western one is continuous, without notable change in form or direction, with the till ridge. The latter is an esker in form but its material is that of a submarginal moraine. Its northeastward extension presents some of the characters of a pitted sand plain or esker-delta, but it is complicated by the presence of the clay conglomerate and the kame-like sand and gravel knobs. The general indications of the surrounding country are that the Saginaw ice here moved to the east, southeast and south, but it seems impossible to interpret the local phenomena upon that supposition. If the till ridge is a frontal moraine the direction of ice movement was northward. During the formation of this moraine the ice was traversed by tunnels or cracks which surrounded a block occupying the High Lake basin. These openings formed to some extent the channels of glacial drainage, but the writer finds himself unable to conceive how any considerable quantity of the sand, gravel and boulders in the ridges could have been transported by running water and deposited in such irregular and disconnected heaps. The clearest mental picture he is able to construct is that of a high narrow crack or tunnel, perhaps gradually transformed by the collapse of its roof into an ice-walled canyon open to the sky. Into this crevasse the surface débris slid or was irregularly dumped until it was filled to a height considerably above the tops of the present ridges. The subsequent removal of the walls permitted the pile to spread and assume such form as gravity and the coherence of the material permitted. In form the main gravel ridge is much like the pile of iron ore seen in the yard of a modern blast furnace and perhaps it may be regarded as a dump moraine formed under peculiar conditions. At the position of the large kettle the crack must have divided around an isolated ice-block or island which, although not more than two hundred yards in diameter, persisted through the whole period of filling, the bulk of the material being deposited equally on each side of it. Genetic classification of the system as a whole seems impossible. It might be called an esker-kame-moraine.

About five miles west of High Lake, along the valley of Turkey Creek lies the system of eskers shown in Fig. 2. The valley is here from one fourth to one half a mile wide and bounded by well defined bluffs. The valley floor is occupied for several miles by a peat bog containing a dozen small lakes. About one mile of it is traversed by a series of sand ridges and mounds disposed in characteristic eskerine patterns and contours. The direction of drainage was plainly northward. The main ridge is 200 to 300 feet wide and fifteen to twenty feet high with a rather flat crest rising in occasional knolls to twenty-five and thirty feet. The northern portion of the series consists of a group of irregular islands and mounds of considerable mass which is perhaps the representative of an esker-delta. No excavations or cuts have been made and the surface shows no material but sand with an occasional small boulder. The arrangement of the ridges and mounds is such as to enclose between them and the bluff the basin of Gordy's Lake of about fifty acres extent and thirty-five feet in depth. High and Gordy's lakes owe their existence and outline to the presence of eskers and they seem worthy to constitute a distinct species of glacial lakes to be known as esker lakes.

CHARLES R. DRYER.

INDIANA STATE NORMAL SCHOOL,
Terre Haute.

CORRELATION OF THE KINDERHOOK FORMATIONS OF SOUTHWESTERN MISSOURI.

In a recent geological report on Greene county, Missouri,[1] by Professor Edward M. Shepard, the stratigraphy of a portion of the southwestern part of the state surrounding the city of Springfield, has been described in detail. Some of the correlations proposed for the Kinderhook formations, however, are erroneous because of the almost entire disregard of paleontological evidence. The Kinderhook formations in the area are not abundantly fossiliferous, and unless careful search be made for fossils they may be easily overlooked. All the principal formations, however, contain distinctive faunas which furnish the data for a definite correlation of the beds.

The formations described by Shepard that must be included in the Kinderhook, are as follows, beginning with the lowermost, the names being those used in the report:

1.	Eureka or black shale	0 to 4 feet
2.	King limestone	1 to 15 feet
3.	Sac limestone	1 to 18 feet
4.	Phelps sandstone	0 to 4 feet
5.	Louisiana limestone	0 to 8 feet
6.	Hannibal sandstone and shale	10 to 90 feet
7.	Chouteau limestone	3 to 30 feet

The most conspicuous of these formations in the region covered by the report are the Sac limestone, the so-called Hannibal sandstone and shale and the so-called Chouteau limestone. In his geological map Shepard has recognized only three divisions in the series which correspond in general with the three formations just named. The Eureka shale and the Phelps sandstone are also formations which are apparently worthy of separate definition, but the King limestone and the so-called Louisiana limestone may prove, upon sufficient investigation, to be nothing but lithologic facies of the Sac limestone. The strict correlation of the formations called Louisiana limestone, Hannibal sandstone and shale, and Chouteau limestone with the formations recognized under these names in the central and northeastern portion of the state cannot be sustained, as will be shown in the following pages, and in the present paper the names Northview sandstone and shale and Pierson limestone will be substituted for Hannibal sandstone and shale and Chouteau limestone.

---

[1] A Report on Greene county, by EDWARD M. SHEPARD, Geol. Survey of Missouri, Vol. XII, pp. 12–245 (December 1898).

The four lowermost of the formations in the preceding list, were referred by Shepard to the Devonian, but in view of the well defined Kinderhook faunas that are present in the Eureka shale and the Sac limestone, such a correlation cannot be sustained.

Eureka shale.—This formation has been recognized by Shepard in but few localities in the area covered by his map, and is restricted, for the most part, to the southwestern portion of the region where it attains its maximum thickness. Outside of this portion of the area, a few inches of shale have been recognized at several localities lying above the magnesian limestones, which are referred to this formation. Near Frazer's, at the chief locality for the Eureka shale cited by Shepard, the following fossils were collected by the writer:

1. *Lingula* sp. cf. L. *subspatulata* M. & W.
2. *Orbiculoidea* sp. undet.
3. *Chonetes* sp. cf. *C. logani* N. & P. or *C. ornatus* Shum.
4. *Ambocoelia parva* Weller.
5. Phyllocarid crustacean.
6. Fish scales ?

The most common fossils in the fauna are the Lingulas, in this respect simulating the Eureka shale fauna of northern Arkansas which has been described by Williams.[1] *Orbiculoidea* is not recorded from Arkansas by Williams, although there is no reason why the genus should not be present in the Eureka shale of that state. The *Chonetes* found at Frazer's is evidently identical with one of the species of this genus recorded by Williams, and is probably identical with one of the common Chouteau species of the genus. *Ambocoelia parva* was first described from the Northview sandstone, and the specimens from the shale seem to be indistinguishable from the types of the species except that they are more or less crushed. No crustaceans are recorded by Williams, but Phyllocarid crustaceans similar to those noticed in the fauna are not of uncommon occurrence in similar shale formations. Fish remains were detected by Williams in the Arkansas beds. No specimens of the *Leiorhynchus subspatula* noticed by Shepard[1] from this locality were detected by the writer.

---

[1] Am. Jour. Sci. (4), Vol. VIII, pp. 139–152.

Notwithstanding the presence of some forms in this fauna at Frazer's which have not yet been recognized in the Eureka shale of Arkansas, and the absence of others which are known to occur there, when we consider the poorly preserved nature of the fossils in all the localities and the stratigraphic relations of the beds containing them, the similarity between the faunas of the two regions is sufficient to establish the correlation, in a general way, of the beds containing them.

In regard to the age of the Eureka shale fauna in Arkansas Williams[2] says:

> The fauna of these fine shales in Arkansas, terminating and following the black shales, is unmistakably much higher than the Genesee black shale of New York. Faunally it is the correlative of the Louisiana or lithographic limestone, and is thus as late as the Kinderhook stage of the Eocarboniferous.

The beds indicated in the quotation are the fine green shales which always follow without any break in the sedimentation, the typical black Eureka shale when the two members are both present. Usually the black shales, in Arkansas, contain almost no fossils save *Lingulus*, but at one locality on War Eagle Creek a fauna from the black shales is noted which does not differ essentially from that in the greener beds.

Recent careful studies among the Kinderhook faunas of the Mississippi valley have given a basis for a more definite correlation of the Eureka shale fauna than Williams was able to make.[1] As will be shown, the fauna may be correlated definitely with that of the upper Kinderhook, that portion of the series which lies above the Chonopectus sandstone in the Burlington section.

---

[1] Loc. cit., p. 67.

[2] Loc. cit., p. 149.

The specimens referred to *Cyrtina acutirostris* by Williams are probably not representatives of the typical form of this species, but of a variation which may prove to be an undescribed form which is present in the Sac limestone and in the typical Chouteau limestone. *Spirifer marionensis* is a common species in the upper Kinderhook. The species recorded as *S. ? compactus* Meek is certainly *S. peculiaris* Shum., a common and variable species in the upper Kinderhook which possibly runs up into the lower portion of the Burlington limestone. *Athyris hannibalensis* is only a small form of *A. lamellosa*, and the two are not specifically distinct. It is common in the upper Kinderhook of southwestern and southeastern Missouri, but has not been recognized in the Burlington section. The three forms of *Chonetes* recorded by Williams are probably all present in the upper Kinderhook. The species of *Productus* referred to *P. hallanus* Walc. is not that species, but the specimens so identified are identical with a common species in the Sac limestone which has also been recognized in the typical Chouteau of central Missouri and in the upper beds of the Kinderhook in southeastern Missouri. The pedicle valve resembles *P. hallanus*, but the brachial valve does not have the concentric markings of that species. The orthids recorded by William are like those in the upper Kinderhook faunas elsewhere. *Leptaena rhomboidalis* is present in almost every upper Kinderhook fauna but has not been recognized in the Chonopectus fauna, nor in that of the Louisiana limestone. The additional species recorded by Williams afford little evidence as to the age of the fauna.

---

[1] Many of the Arkansas collections studied by Williams were made by the writer as an assistant to Professor Williams under the auspices of the United States Geological Survey. These collections were also carefully studied by the writer in Professor Williams' laboratory during the winter of 1894–5.

The paleontological evidence, as shown above, points conclusively to the Kinderhook age of the Eureka shale of Arkansas, and not merely may the fauna be correlated with the Kinderhook in general, but with that portion of the Kinderhook which is represented by the Chouteau limestone of central Missouri. The fauna is younger than the Chonopectus fauna of the Burlington section, and is also younger than the fauna of the Louisiana limestone if the generally accepted view as to the stratigraphic position of this formation, at the extreme base of the Kinderhook, be the correct one.

The Eureka shale in Missouri, as described by Shepard, is doubtless a stratigraphic continuation of the Arkansas formation, though the actual time of its deposition may have been a little earlier. The Kinderhook sea, in southwestern Missouri and northern Arkansas, is believed to have been transgressing upon the land to the southward. The Eureka shale facies of sedimentation is believed to have been a transgressing formation associated with the trangression of the sea to the southward, it being the initial sedimentation upon the newly submerged land surface. This formation, therefore, in the region covered by the Greene county report, was probably deposited a little earlier in time than its stratigraphic equivalent in northern Arkansas, as it is followed by the Sac, Northview, and Pierson formations. In northern Arkansas this same stratigraphic unit represents the final stages of the Kinderhook, it being immediately followed by the St. Joe marble whose fauna indicates the Burlington age of the formation. The black Eureka shale in Arkansas, with its associated greenish shale beds and the equivalent Sylamore sandstone, may be considered as the sole representatives of the Kinderhook in that state, the time of their deposition being the final stages of the Kinderhook epoch.

Sac limestone.—The King limestone, described by Shepard, has not been studied by the writer. It is said to be[1] "rarely over a foot or two in thickness except outside and south of the area." A further statement is made in regard to the formation[2] to the effect that "to the south . . . . it underlies, directly, the Phelps sandstone, the Sac limestone being absent." This manner of occurrence would seem to indicate that the formation was but a facies of the Sac limestone, it being thin or almost absent where the typical facies of that formation is well developed, becoming thicker and replacing the lithologic facies described as the Sac limestone, to the south. A careful search for fossils should be made in the limestone in order to determine whether or not its fauna is the same as that in the Sac limestone.

---

[1] Loc. cit., p. 71.

[2] Loc. cit., p. 72.

The typical facies of the Sac limestone is well exposed in numerous outcrops along the Sac River and its branches in the northern portion of Greene county, the name of the formation being selected by Shepard[1] because of this occurrence. It is a hard, bluish gray, compact limestone with a maximum thickness of eighteen feet, usually deposited in beds of from six to ten inches thick with thin greenish shaley partings between the beds. The rock has been quarried somewhat extensively at several points and shipped to Springfield to be used as curbing. Shepard referred the formation with those beneath it, to the Devonian, considering it to be of Hamilton age. No fossils were secured by him in the formation itself by means of which such a correlation could be established, but in the overlying Phelps sandstone, numerous waterworn fragments of fish-teeth were secured, some of which were identified as *Ptyctodus calceolus*. This genus of fishes is usually considered to be limited to the Devonian, and its presence in beds overlying the Sac limestone was considered to be sufficient evidence to justify the reference of the underlying beds to the Devonian. A study of the invertebrate fauna of the Sac limestone, however, serves to definitely correlate the formation with the lower portion of the Chouteau limestone of central Missouri, and leads to the conclusion that either the waterworn fragments of fish-teeth have been wrongly identified, or that the genus *Ptyctodus* has a higher geological range than has hitherto been supposed.

Although no fossil fauna was secured from this formation by Shepard, the Sac limestone is really fossiliferous in most localities where it is exposed, and frequently affords beautifully preserved specimens. One of the best fossil localities in the formation known to the writer, is at an old quarry about eight miles northeast of Springfield, east of the Fair Grove road where it crosses the north branch of the Little Sac. The species collected at this locality will be enumerated, with notes on their occurrence elsewhere.

---

[1] Loc. cit., p. 74.

1. *Platycrinus ollicula* S. A. M.
2. *Platycrinus annosus* S. A. M.
3. *Platycrinus absentivus* S. A. M.

   All three of these species of Platycrinus were originally described from the Chouteau limestone of Pettis county, Missouri.
4. *Dichocrinus* sp. undet. A single specimen of this crinoid has been observed. It is too imperfect for specific identification, but it resembles *D. inornatus* from the upper Kinderhook beds at Le Grand, Iowa.
5. *Schizoblastus roemeri* Shum. This species originally described from the Chouteau limestone at Providence, Missouri, is one of the commonest species in the Sac limestone at the locality under discussion.
6. *Leptaena rhomboidalis* Wilck. This species is entirely absent from the lower Kinderhook beds at Burlington, Iowa, making its first appearance in the upper "Yellow Sandstone," bed No. 5.[1] The species is also absent from the Louisiana limestone fauna of the lower Kinderhook, but is universally present in the upper Kinderhook.
7. *Chonetes logani* N. & P. This little species is particularly characteristic of the oolite bed No. 6[2] of the Burlington section. It is also possible that *C. ornatus* Shum., from the typical Chouteau limestone, is not specifically distinct.
8. *Productus blairi* S. A. M. This species was originally described from the Chouteau limestone of Pettis county, Missouri.
9. *Productella concentrica* H. This species occurs abundantly in the Chouteau limestone of central Missouri, and is also a member of the oolitic limestone (bed No. 6) fauna at Burlington, Iowa.
10. *Schizophoria swallovi* H. The specimens referred to this species are smaller than the normal form of the species in the Burlington limestone. Specimens agreeing in all respects with those from the Sac limestone, are also present in the typical Chouteau limestone.

---

[1] Iowa Geol. Survey, Vol. X, p. 76.

[2] Loc. cit., p. 77.

11. *Rhipidomella burlingtonensis* H. A small form of this species is present in the fauna, which agrees in all respects with specimens from the Chouteau limestone.
12. *Pugnax missouriensis* Shum. The Sac limestone specimens of this species are indistinguishable from specimens of the same species from the Chouteau limestone at Chouteau Springs, Missouri.
13. *Athyris prouti* Swall. This species has not been seen from the Chouteau limestone of central Missouri, but is a common species in the upper portion of the Kinderhook near Sulphur Springs, Missouri.
14. *Athyris* sp. undet. A small species somewhat resembling the Devonian *A. fultonensis* occurs in the Sac limestone fauna, and the same form is present in the Chouteau limestone at Providence, Missouri.
15. *Cleiothyris* sp. undet. Specimens of a small lenticular species resembling *C. hirsuta* are present in the fauna, and the same species occurs in the Chouteau limestone at Providence, Missouri.
16. *Spirifer peculiaris* Shum. This is one of the commonest species of the Sac limestone fauna, as it is also of the Chouteau limestone of central Missouri. The same or a closely allied species occurs in bed No. 5 at Burlington.
17. *Spirifer latior* Swall.? This species was originally described from the Chouteau limestone of Cooper county, Missouri, but no illustrations of it have ever been published. The Sac limestone specimens are identified thus with some doubt, but in any event a species identical with them occurs in the Chouteau limestone of Pettis county.
18. *Spirifer striatiformis* Meek? This identification is only provisional, but specimens of the same species occur in the Chouteau limestone in Pettis county.
19. *Syringothyris missouri* H. & C. This species is only known elsewhere from the Chouteau limestone at Chouteau Springs, Missouri.
20. *Cyrtina* sp. undet. The same species has been recognized from the typical Chouteau limestone.
21. *Dielasma* sp. undet. A rather large, smooth species of this genus is present in the fauna, which is apparently identical with specimens from the Chouteau limestone of Pettis county.
22. *Capulus* sp. undet. Several forms of this genus are present in the fauna which may belong to several distinct species.
23. Corals and Bryozoa. Several undetermined species of corals and bryozoa of little diagnostic value, occur in the fauna.
24. Fish teeth. Fragments of fish teeth are not uncommon in the fauna.

From the list of fossils just given it will be seen that the fauna of the Sac limestone corresponds closely with that of the typical Chouteau limestone of central Missouri, and more especially with the lower division of the Chouteau limestone as described by Swallow.[1] There is no foundation whatever for correlating it with the Hamilton formation of the Devonian, but several of the species are also present in beds 5 and 6 of the Kinderhook at Burlington, Iowa.

The formation referred by Shepard to the Louisiana limestone, is described as follows by that author :[2]

> The lowest member of the Carboniferous is not so variable in composition and texture as the other two. It frequently, however, possesses such lithologic characters as to make it difficult to distinguish it from the associated Devonian rocks. As only a few obscure fossils have been found in this region, its identification is dependent entirely upon position and lithologic characters.

The Devonian formation referred to in the above quotation is the Sac limestone. The difficulty in separating the so-called Louisiana limestone from the Sac limestone is frequently indicated by Shepard by such statements as the following:

> P. 85 : . . . . an outcropping of what seems to be some eight or ten feet of Louisiana, though it may prove to be a somewhat modified form of Sac limestone ; p. 76 : it is barely possible that this particular rock may be Louisiana, and not the Sac limestone ; p. 77 : there is frequent difficulty, on account of lithologic characters, in separating it [the Sac limestone] from the Louisiana when the Phelps sandstone is absent ; p. 77 : it is a noticeable fact that, when the Devonian [the Sac limestone] is present, the Louisiana limestone is usually, though not always, absent.

Among the localities mentioned for the Louisiana limestone, the best exposure where both this formation and the Sac limestone are present, is said to be at the Newton mound,[3] and the description of its stratigraphic position at this locality is as follows: "Immediately underlying the Hannibal shales and overlying the Phelps sandstone, are ten feet of this limestone." The Phelps sandstone at this same locality is described in another place[1] as follows: "a number of fragments of the typical sandstone with fish teeth were found on the slope. A hurried search did not discover this sandstone uncovered." If this last statement be correct, it is difficult to see how the fact stated in the first of the above quotations can be demonstrated. Another locality mentioned where the Louisiana limestone is said to be "associated with the Devonian" is on the Cochran farm. The so-called Devonian described at this locality is the Sac limestone and "loose fragments" of Phelps sandstone in which "no fish teeth were found." In neither of these localities is it demonstrated that the so-called Louisiana limestone and the Sac limestone are distinct formations separated by the Phelps sandstone. The loose fragments supposed to belong to this sandstone can be of no value in elucidating the stratigraphy. In none of the other localities given for the Louisiana limestone is there any evidence given to show that the formation is distinct from the Sac limestone, and the careful reader of the Greene county report is forced to the conclusion that its author mistook mere lithologic variations of a single stratigraphic unit as two distinct formations. A careful search for fossils, however, should be made in the outcrops of so-called Louisiana limestone, for the purpose of demonstrating its identity with the Sac limestone.

---

[1] Geol. Surv. Mo., Rep. I and II (1855), p. 102.

[2] Loc. cit., p. 84.

[3] Loc. cit., p. 84.

Phelps sandstone.—This formation has been examined by the writer only at its typical locality in the neighborhood of the Phelps mines. It has been recognized by Shepard, however, as a more or less continuous formation throughout the area covered by his report, and is frequently characterized by the waterworn fragments of fish teeth. At the Phelps mines these teeth are somewhat abundant, but are so waterworn that in every specimen observed the original form has been destroyed. Some of these specimens have been identified by Shepard as *Ptyctodus calceolus*, and it was chiefly from the evidence of this identification, with no knowledge of the invertebrate fauna of the Sac limestone, that the Phelps sandstone was referred to the Devonian, such a reference carrying with it, of necessity, all the underlying beds down to and including the Eureka shale. This sandstone resembles, lithologically, the Sylamore sandstone of Arkansas; both formations carry fish remains and also numerous black phosphatic nodules.

---

[1] Loc. cit., p. 81.

Northview sandstone and shale. — In the older geological reports these beds have been known as the Vermicular sandstone and shales from the abundance of worm burrows which occur in the sandstones. Shepard[1] has considered these beds to be the equivalent of the Hannibal shales of the Mississippi River section which are supposed to lie beneath the Chouteau limestone, and he has so designated them in his report. These beds in southwestern Missouri, however, are certainly not the equivalent of the typical Hannibal shales, if the relationship of that formation to the remainder of the Kinderhook series be properly understood, and as they possess a characteristic individuality of their own throughout a considerable geographic area, it seems advisable to designate the formation by a special name. The sandstones of the formation are abundantly fossiliferous near Northview, in the western edge of Webster county, and therefore this name is suggested for the formation.

Shepard's investigations have shown that the formation has a thickness ranging from ten to ninety feet. It is typically made up of two members, a lower bluish shale and an upper fine-grained yellowish sandstone. The two members of the formation grade from one into the other with no sharp line of separation, and one member is frequently thickened at the expense of the other, the lower shale member being the most peristent.

The fauna of this sandstone at Northview has been described in detail in another place,[2] and contains the following species.

1. *Zaphrentis* sp. undet. A few fragments of specimens of this genus have been observed.
2. *Scalarituba missouriensis* Weller. This is the name which has been applied to the worm borings which penetrate the sandstone in all directions.

---

[1] Loc. cit., p. 86.

[2] Kinderhook Faunal Studies. I. Fauna of the Vermicular Sandstone at Northview, Webster county, Missouri. Trans. St. Louis Acad. Sci., Vol. IX, pp. 9–51.

3. *Orthothetes inaequalis* Hall? In the paper cited above, this shell was identified as *O. chemungensis*. It is probably identical with one of the species in the upper Kinderhook beds at Burlington, but may not be the *O. inaequalis*.
4. *Schizophoria swallovi* Hall. The specimens of this species resemble those from the subjacent Sac limestone, and also those from the superjacent Pierson limestone, but are usually larger than the Sac limestone specimens.
5. *Rhipidomella burlingtonensis* Hall. The specimens of this species are not unlike those from the other Kinderhook formations of the region, but are usually larger than the Sac limestone specimens.
6. *Chonetes illinoisensis* Worthen? The specimens so identified should perhaps rather be referred to *C. multicosta* Win., described from the "yellow sandstone" at Burlington, Iowa.
7. *Productella concentrica* Hall. A single individual of this species resembles specimens of the same species from Burlington, Iowa.
8. *Spirifer marionensis* Shum. This is one of the most abundant species in the fauna of the Louisiana limestone at its typical exposures. It is also a common species in the oolite bed at Burlington and occurs in the subjacent "yellow sandstone" at the same place, as well as being more or less common in most of the upper Kinderhook faunas.
9. *Spirifer striatiformis* Meek? This species is probably identical with the one so identified from the Sac limestone.
10. *Syringothyris carteri* Hall. Several specimens from Northview have been referred to this species, although the characteristic syrinx and punctate shell structure of the genus have not been observed.
11. *Ambocoelia parva* Weller. This species has only been observed in this fauna and in the Eureka shale.
12. *Athyris lamellosa* Lev. This species is a common one in the superjacent Pierson limestone, and is also a member of the typical Chouteau limestone fauna.
13. *Cleiothyris* sp. undet. These specimens are possibly identical with those in the Sac limestone.
14. *Dielasma* sp. undet. This shell is perhaps the same as that described by Winchell as *Centronella allei* from the upper "yellow sandstone" at Burlington.
15. *Crenipecten winchelli* Meek? This is a species which was originally described from the Waverly sandstones of Ohio.
16. *Crenipecten laevis* Weller. This species was described from Northview, and is not known elsewhere.

17. *Pernopecten cooperensis* Shum. This is one of the commonest species in the Northview sandstone, and is also one of the most characteristic species of beds 5 and 6 of the Burlington section. It was originally described from the Chouteau limestone of Cooper county, Missouri, and is a common shell in some beds of the Chouteau limestone.
18. *Modimorpha northviewensis* Weller. This species has only been recognized at Northview.
19. *Macroden* sp. undet. This species has not been identified, but the genus is represented in the upper "yellow sandstone" fauna at Burlington by a very common species. The genus is also represented in the typical Chouteau limestone.
20. *Cardiopis radiata* M. and W. This species originally described from the goniatite limestone at Rockford, Indiana, also occurs in the Chouteau limestone in Pettis county, Missouri.
21. *Cardiopsis erectus* Weller. This species was first described from Northview, and has not been recognized elsewhere.
22. *Palaeoneilo* sp. undet. This species was formerly identified with a query as *P. constricta* Con., but it is probably distinct. It is closely allied to *P. microdonta* Win. of the upper "yellow sandstone" at Burlington, but is usually larger.
23. *Palaeoneilo truncata* H. This species, originally described from the Waverly sandstones of Ohio, is represented in the upper "yellow sandstone" at Burlington by *P. barrisi* W. & W. a similar but smaller species. The genus *Palaeoneilo* does not occur in the Chonopectus fauna at Burlington, and has not been recognized in any of the lower Kinderhook faunas.
24. *Schizodus aequalis* Hall. This is a Waverly sandstone species, and has not been recognized elsewhere in the Kinderhook.
25. *Elymella missouriensis* M. & G. This species was originally described from the Chouteau limestone of Pettis county, Missouri.
26. *Promacrus websterensis* Weller. This was described as a new species from Northview.
27. *Promacrus cuneatus* Hall. In the description of the fauna of the Chonopectus sandstone,[1] this species was provisionally included. Since that time, however, through the courtesy of Dr. E. O. Hovey, of the American Museum of Natural History, the type specimen of *P. cuneatus* has been examined by the writer, and it proves to have come from the upper "yellow sandstone," bed No. 5, at Burlington. The genus *Promacrus* is represented by several species in the

---

[1] Kinderhook Fauna Studies. II. Fauna of the Chonopectus Sandstone at Burlington, Iowa. Trans. St. Louis Acad. Sci., Vol. X, pp. 57–129.

typical Chouteau limestones of central Missouri. It is not known anywhere in the lower Kinderhook beds, and is probably a characteristic form of the upper Kinderhook faunas.

28. *Sanguinolites websterensis* Weller. This species was described as new from Northview, but probably occurs also in the Waverly sandstones of Ohio.
29. *Edmondia* sp. undet. This species was originally identified as *E. burlingtonensis* W. & W., but an examination of the types of that species from the Chonopectus sandstone have led to the conclusion that the two shells are not specifically identical.
30. *Edmondia missouriensis* Weller. This species was described as new from Northview.
31. *Tropidodiscus cyrtolites* Hall. This species, originally described from the goniatite limestone at Rockford, Indiana, is also recorded from the Waverly sandstones of Ohio.
32. *Euphemus?* sp. undet.
33. *Bucania?* sp. undet.
34. *Bellerophon* sp. undet.
35. *Mourlonia northviewensis* Weller. This was described as a new species from Northview.
36. *Pleurotomaria* sp. undet.
37. *Platyschisma missouriensis* Weller. This was described as a new species from Northview.
38. *Straparollus* sp. undet.
39. *Phanerotinus paradoxus* Winch. This species, first described from Burlington, is probably a member of the upper "yellow sandstone" fauna at that locality.
40. *Capulus* sp. undet.
41. *Porcellia rectinoda* Win. (?) The correct horizon of the original types of this species at Burlington is not known. Two other members of the genus, however, occur in the Chonopectus sandstone. The genus is also known to occur higher up in the Burlington limestone.
42. *Loxonema* sp. undet. This species is of the general form of specimens which are not uncommon in the Chouteau limestone in Central Missouri.
43. *Orthoceras indianense* Hall. These specimens, formerly identified as *O. Chemmigense* Swall., are probably identical with a form common in the oolitic limestone (bed No. 6) at Burlington, which may probably be identified with *O. indianense* of the goniatite limestone at Rockford, Indiana.
44. *Triboloceras digonum* M. & W. This species is a common one in some portions of the Chouteau limestone of central Missouri.

45. *Proetus* sp. undet.
46. *Spirophyton* sp. undet. These fucoid markings are abundant everywhere in the sandstone, and with the worm borings are the only fossils which are always recognizable in this formation.

When the description of the Northview fauna was published no differentiation of the faunas of the "yellow sandstone" at Burlington was possible. Since that time, however, a study of the type collections from that locality has shown that two quite distinct yellow sandstone faunas occur.[1] The lower is characterized by *Chonopectus fischeri* N. & P., and the bed containing it, bed No. 2, has been called the Chonopectus sandstone. The upper yellow sandstone is characterized by the presence of *Pernopecten*, *Promacrus*, and *Palaeoneilo*, genera which are wanting from the Chonopectus fauna. These same genera, however, are among the most characteristic forms of the Northview sandstone, and all of them are also present in the fauna of the typical Chouteau limestone of central Missouri. The faunas of the Northview sandstone and of the upper yellow sandstone at Burlington may be considered as analagous, and they may without hesitation be considered as one facies of the upper Kinderhook or Chouteau fauna.

The Northview shales are usually quite barren of fossils, but at a few localities they are abundant. They are mostly brachiopods and corals, but no complete list of species can be given in this place. The collections in Walker Museum contain only a few specimens from this bed near Bolivar in Polk county, the species represented being *Athyris lamellosa*, *Reticularia cooperensis*, and *Rhipidomella burlingtonensis*. These species are all present in the fauna of the typical Chouteau limestone elsewhere.

Pierson limestone.—This is a fine-grained, buff colored, gritty limestone having a maximum thickness, according to Shepard,[2] of thirty feet, being the formation designated by him as the Chouteau limestone. In view of what has already been written in regard to the faunas of the Sac limestone and the Northview sandstone, it will be recognized that the formation is by no means an exact equivalent of the Chouteau limestone of central Missouri, but represents merely the upper portion of that formation. The formation is well exposed along Pierson Creek near the zinc mines, and since it possesses an individuality of its own as a formation, over a rather extensive area, it may be designated as the Pierson limestone. The formation is frequently non-fossiliferous, but fossils often occur and are usually well preserved. One of the best fossil localities is on the south branch of the Little Sac Creek, about two miles north of Lyman station on the St. Louis and San Francisco railroad. At this locality the following fauna was collected which may be taken as a typical representation of the fauna of the whole formation.

---

[1] Iowa Geol. Surv., Vol. X, p. 79.

[2] Loc. cit., p. 83.

1. *Zaphrentis* sp. undet. A single imperfect specimen of this genus is the only coral of the fauna.
2. *Leptaena rhomboidalis* Wilck. This species is of frequent occurrence in the fauna.
3. *Orthothetes* cf. *O. inflatus* W. & W. A species similar to *O. inflatus*, but much flatter, is rather common in the fauna. The same shell is associated with *O. inflatus* in oolitic bed No. 6 of the Burlington section.
4. *Chonetes* sp. undet. A large species frequently having a width of more than twenty ^{mm} is not uncommon in the fauna. It resembles *C. illinoisensis* Worthern, but is much larger and should perhaps be identified as *C. shumardianus* DeKon.
5. *Chonetes logani* N. & P. ? A species having the general form of *C. Logani* is not uncommon in the fauna, but the preservation is not such as to exhibit the characteristic surface markings of that species.
6. *Productus arcuatus* Hall. This species is particularly abundant in the oolite bed at Burlington, and the Pierson limestone specimens are of the typical form.
7. *Productus burlingtonensis* Hall. Specimens of this species indistinguishable from those in Burlington limestone, occur in the Pierson limestone.
8, *Productus laevicostus* White. This species makes its first appearance in the Chonopectus sandstone of the Burlington section, and ranges up into the base of the Burlington limestone.
9. *Productus punctatus* Martin. Specimens of this species are not uncommon in the Pierson limestone. In the Burlington section it makes its first appearance in bed No. 7, the topmost bed of the Kinderhook at that locality.

10. *Schizophoria swallovi* Hall. Specimens of this species identical with those in the Burlington limestone are present in this fauna.
11. *Rhipidomella burlingtonensis* Hall. Individuals of this species from the Pierson limestone resemble those from the Northview sandstone, and are more nearly like typical representatives of the species from the Burlington limestone than are the Sac limestone specimens.
12. *Camarophoria* sp. undet. This species is of the general form of *C. caput-testudinis* White, the types of which are from the base of the Burlington limestone, and bed No 7 of the Kinderhook at Burlington. The Pierson limestone species, however, differs from *C. caput-testudinis* in being a much smaller and flatter shell.
13. *Rhynchonella cooperensis* Shum. This species was originally described from the Chouteau limestone of Cooper county, Missouri.
14. *Athyris lamellosa* Lev. This is one of the commonest species of the fauna, and specimens from the Pierson limestone are indistinguishable from those in the Burlington limestone.
15. *Spirifer marionensis* Shum. This is the same species that occurs in the Northview sandstone. It is one of the commonest members of the Pierson limestone fauna and also of the oolitic limestone fauna at Burlington.
16. *Spirifer latior* Swall.? The specimens identified as this species are not different from those in the fauna of the Sac limestone.
17. *Spirifer peculiaris* Shum. The Pierson limestone representatives of this species are not unlike those from the Sac limestone.
18. *Spirifer grimesi* Hall. This Burlington limestone species is represented by typical individuals in the Pierson limestone.
19. *Spirifer* sp. undet. This species has the high area of Syringothyris, but lacks the syrinx, and is apparently not punctate.
20. *Reticularia cooperensis* Swall. This species rarely occurs in the fauna. It is a common form in the typical Chouteau limestone and also occurs in the upper "yellow sandstone" at Burlington.
21. *Dielasma* sp. undet. These specimens have the general form and size of those recorded from the Sac limestone, but usually have more conspicuous lines of growth.
22. *Macrodon* sp. undet. A single imperfect specimen of this genus is the only pelecypod recognized in the fauna.
23. *Orthoceras* sp. undet. Fragmentary specimens of a species of Orthoceras are not uncommon in the fauna.

In the Pierson limestone fauna we find a disappearance of the pelecypod element which is so characteristic of the Northview sandstone, and a return of the brachiopods. Some of these brachiopods are common to the Sac limestone, but there are introduced several species, such as *Spirifer grimesi*, *Productus burlingtonensis*, *Productus punctatus*, and *Athyris lamellosus* (which was also present in the Northview sandstone), which pass upward and connect the fauna with that of the Burlington limestone above.

Conclusions.—A critical examination of the Kinderhook faunas of southwestern Missouri, shows that the entire series of strata in that region referable to this division of the Mississipian series are to be correlated with the upper division of the Kinderhook, or the Chouteau limestone of central Missouri. This Chouteau fauna is not one uniform fauna throughout, but exhibits at least two rather well-defined facies, one brachiopod fancies generally characteristic of the limestones and another pelecypod facies characteristic of the more clastic sediments. In Greene county, Missouri, the brachiopod facies is present in the Sac limestone and the Pierson limestone, while the pelecypod facies is present in the Northview sandstone.

In the Burlington section, beds 5, 6, and 7 are apparently to be correlated with the Greene county formations, and in the faunas of these three beds the same brachiopod and pelecypod facies are exhibited, but in a different order, the pelecypod facies occupying bed 5, and the brachiopod facies beds 6 and 7.

In central Missouri, the region of the typical Chouteau limestone, opportunity has not been offered to study these faunas in situ. Among the material received from that region, however, the same two faunal facies may be recognized, though it is impossible to work out their interrelations without careful field investigation.

These two faunal facies apparently lived contemporaneously throughout the area covered by the upper Kinderhook sea, each one occupying those portions of the region where the local conditions were best adapted to its development, shifting about with local changes in the environment, and each one going on with its developmental changes with the progress of time. The faunas of the Northview sandstone and of bed No. 5 at Burlington, have so much in common that they may be considered as representatives of a single fauna, yet they may not have been and probably were not strictly contemporaneous. They simply indicate that at some stage during the limited time period in which they both belong, there were present in each of these widely separated regions, conditions suitable for the existence of the same general assemblage of species.

The Chonopectus fauna, which underlies these faunas in the Burlington section, is not represented in southwestern Missouri; neither is the typical Louisiana limestone fauna present in the region.

STUART WELLER.

THE UNIVERSITY OF CHICAGO.

PROBLEM OF THE MONTICULIPOROIDEA. II

CRYPTOSTOMATA

CRYPTOSTOMATA are quite generally classed as Bryozoa, but their reference as such can still be treated as doubtful. They occupy, in fact, a central position in the disputed field of Paleozoic tabulate fossils. They are quite inseparable from Trepostomata which are most often classed as Cœlenterata. To prove them undoubtedly Bryozoa is to prove Trepostomata such also. To fail in that proof permits the latter to be classed as Tabulata, true Cœlenterata, and the Cryptostomata should then be carried with them.

Four similar groups of tabulate corals and bryozoons appear for their first geologic occurrence in the Ordovician (Lower Silurian). The Tabulata, or Alcyonarian corals, are there represented by a few but typical species, the Trepostomata are locally in great numbers, and with them are many Cryptostomata and a few Cyclostomata, the last being true Bryozoa. To the top of the Paleozoic these four groups remain associated, but there the Cryptostomata become extinct. Only in middle Mesozoic the fifth group, comprising the Chilostomata to which most living Bryozoa belong, appears at a time when even the Trepostomata have quite disappeared. The fifth and last group seems to come in suddenly, as did the others. Evidently the record is incomplete as to their origin, and the missing evidence has therefore to be supplied. Some Cryptostomata resemble in all ways the Trepostomata and these the Tabulata; others somewhat nearly simulate the Cyclostomata; and again it has been suggested[1] that they "are nothing more than Paleozoic Chilostomata," differing from these, however, in several ways. The problem centers about the Cryptostomata.

Besides this interest which the problem of phylogenic relationship affords to the paleontologist, the geologist finds, or can find, most of them good zone markers. They are not especially difficult to recognize in the field, their more highly specialized shapes of frond and of cell pattern making them rather easier than Trepostomata in that respect. Their separation into species and arrangement in taxonomic divisions is facilitated by reliable macroscopic external characters as a rule. They afford also a great variety of neat cabinet specimens, and, in short, may be recommended as worthy of close acquaintance.

---

[1] See EASTMAN, Text-book of Palæontology, p. 278.

The student will find a ready knowledge of the Trepostomata a great aid to the understanding of Cryptostomata. In the former group one can select a simple supposed primitive skeletal structure, from which the others can be traced with increasing complexity or differentiation. The simplest Cryptostomata compare with the most complex Trepostomata, and, while serial arrangement of differentiated types can be made, the series appear not to begin within this group but in the Trepostomata. It is, therefore, further convenient to begin with species of this group which most resemble those of the other, avoiding also for the present the taxonomic definitions until after representative fossil species have been studied. The newest taxonomic arrangement[1] may conveniently be referred to, however, and this one divides the sub-order into eight families. They may well be arranged in three divisions or series:

Bifoliate	Cylindrical	Fenestrate
1. Ptilodictyonidæ	4. Arthrostylidæ	6. Fenestellidæ
2. Rhinidictyonidæ	5. Rhabdomesodontidæ	7. Acanthocladiidæ
3. Cystodictyonidæ		8. Phylloporinidæ

The relation of the three groups will be discussed later, but any one might be taken first, since they are coördinate, not successive, but related each to Trepostomata.

Our knowledge of the Cryptostomata may be considered fairly complete, although species and perhaps a family remain to be discovered, while others might be eliminated. This task of completing the knowledge of the several species and genera, their fixed and variable characters, is one worthy of attention from whoever may be in favorable position to obtain the fossils. For the present the best literature is not to be taken as alike reliable on all. In extreme cases a fortuitous or abnormal character in specimens of a species may have been mistaken as grounds for a new species, and this being then peculiar may be set up as a new genus, and in turn it affects the family. Owing to the more highly specialized structures as compared to Trepostomata, Cryptostomata are, as said, somewhat easier to learn, but they are more complex to study.

---

[1] EASTMAN, op. cit., p. 278.

For the present purpose a few common, well-known species suffice. Taking the bifoliate group first:

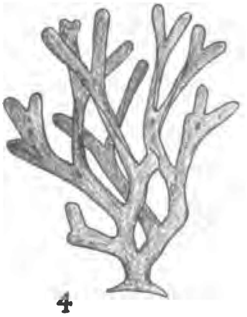
Pachydictya foliata Ulr. (see Plate B, Figs. 1, 2, 3) is a leaf-shaped zoarium about 50^{mm} wide and 1 to 3^{mm} thick, with autocells 0.3 to 0.4^{mm} in diameter growing from a median plane and opening on either side, "bifoliate." It grows at the margin, the erect frond broadening as it increases in height. The growth is not quite uniform and a lobate, undulate shape prevails. The base or broad stem of the frond is therefore the more mature, thicker part, and there the cell increase ceases first and the margin changes to a solid, sharp, or rounded narrow border. Growing margins may also appear on the face of the frond, and when large, arising near the stem, produce a so-called trifoliate frond. A basal expansion incrusted the ground, and if this was broken off a new one developed from above the broken edge. Any injury destroying part of the frond surface gave rise to a similar growth.

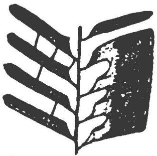
The basal expansion grew perigene, the frond acrogene and so that the zoarial growth and cell increase is normally at the margins only. In the frond the cells arise on either side of a median plane, or so-called mesial plate or lamina, are directed at first vertically, but as younger cells arise between, above them, they turn laterally. Thus an immature or axial and a mature or peripheral region are distinguished. The mesial lamina is built as the extreme wall at the growing edge of the frond.

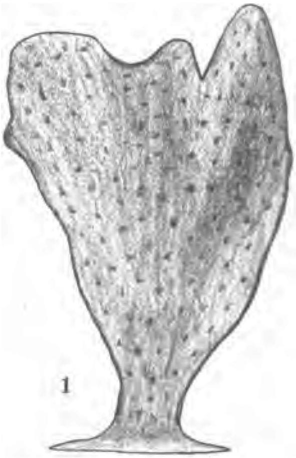
The cells at the beginning, *i. e.* at the mesial lamina, are thin walled, with mesopores at their angles, but later they are separated

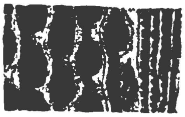
JOUR. GEOL., Vol. IX, No. 2

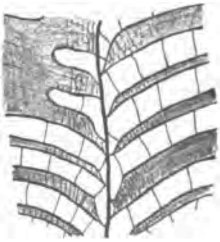
Plate B

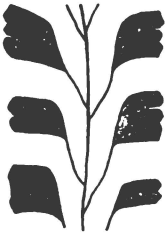

4

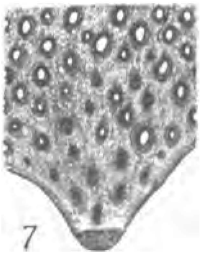

6

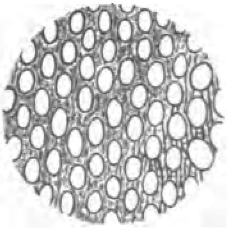

1

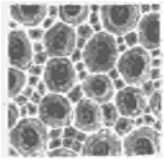

5

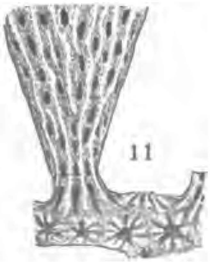

2

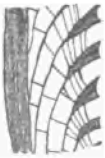

9

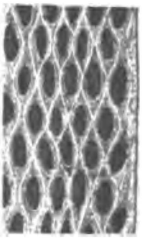

7


3


8


11


12


10

by mesopores, become oval and thick walled. They grow slowly in the peripheral region, to 1 or 1.5^{mm} in length with slightly increasing size. They have a few thin tabulæ, the first one in or near the axial part, the last one often at the aperture. The mesopores are small, numerous, closely tabulated, either distinct, or the tabulæ of neighboring mesopores overlapping in vesiculose way, or again in maturer stages they fill with granulose schlerenchyma. Mesopore walls are nearly always reduced so that those between mesopores are extant only vertically in zoarial direction, but mesopore corners and junction of mesopore walls to autocell wall are always partly developed. Mesopores are rarely distinct at the surface, and their space appears solid between autocells.

The arrangement of the cells is regular, alternating in vertical rows, and the surface pattern is easily used to distinguish the species. Maculæ or solid spots of filled mesopores and filled cells too, are regularly distributed over the surface and next to these the cells are a little larger sized. No cell increase is seen normally in the peripheral or mature region, not even in the maculæ.

The best specimens only show the peristome or circular wall margin papillose, and the interspaces or mesopore tabulæ granulose, or, when some walls are present, granostriate, as the maculæ and zoarial solid border usually are also. The preserved edge of a growing mesial (or median) lamina, I have not seen, but it was probably papillose. Corresponding to these structures, sections show so-called vertical or median tubuli in the midst of the double autocell wall, similar less distinct structures in the schlerenchyma of filled mesopores, and large ones in the mesial lamina. Warts and so-called tubuli on the interspaces sometimes represent reduced mesopore walls. Further details, dimensions, etc., characterizing the species may be passed over here.

One finds characters in *Pachydictya foliata* Ulr., such only as seen in Trepostomata also: bifoliate zoaria (*e. g.*, *Ceramophylla*), occur among them also: axial and peripheral region, autocells and vesiculose mesopores (*Prosopora*, *Fistulipora*), and maculæ differ at most in degree of accentuation. The so-called vertical or median tubuli and the mesial tubuli differ most, but are comparable directly to acanthopores. Their numbers and small size here characterizes the species and genus, however, and unites to the Rhinidictyonidæ.

The question arises again as to what interpretation should be made of the zoarium. Apparently the same interpretation is necessary in *Pachydictya foliata* as in Trepostomata. E. O. Ulrich holds that the successive loculi between autocell tabulæ were each a zoœcium, and the autocell was built by successive generations of polypites and as to median and mesial tubuli, that they were a united system of canals. One may prefer the other interpretation for the following reasons. In any case the necessary interpretation is that the skeleton or zoarium was built by a cortex of zooids over its surface, since the mesopores are outside the cells or zoœcia, and must have been been built by super-zoarial secretion; and likewise the median tubuli which end not in the cells but above them. Admitting a cortex to have covered the zoarium, there is no explanation as to why successive generations instead of a single polypite should have built each cell, or how neighboring cells could have had, one four, the other three or five generations to build it. The so-called tubuli can be interpreted as the structural results of surface projections which they are really seen to be. One can explain the mesial lamina of the zoarium in this way, that, as compared to the palmate zoarium of certain Trepostomata, with long narrow axial surface and flat axial region, the bifoliate zoarium has a still more specialized, narrower axial region and the growth or axial edge being thus very narrow, the cortex bent rather than curved over it, the cell walls coinciding with the line of flexure coming to lie nearly in one plane, and to be more or less thickened. The mesial lamina is at the axial growth center, not as a germinal layer but a wall. The cell increase having ceased at full maturity at any part, the margin ceased to extend rapidly and a filled cell or "nonporiferous" margin formed.

Species of *Pachydictya*, *e.g.*, *P. acuta* Hall, might be described intermediate to *P. foliata* and *Rhinidictya*, but one of this genus may suffice.

Rhinidictya mutabilis Ulr., is bifoliate, with autocells 0.2^{mm} or less in diameter (Plate B, Figs. 4, 5, and 6). It begins apparently as a small thin vertical blade 1 or 2^{mm} wide, with a small basal expansion. It grows in height rapidly, increasing more or less in apical width and branching to the length of 200^{mm} or less. As the zoarium enlarges, its basal expansion widens slowly, the cell apertures filling solid. The base or oldest part of the stalk becomes thick, more or less cylindrical, and solid surfaced. The zoarial branches thicken slowly, having ceased cell increase and built solid narrow margins, the ends either meanwhile growing by cell increase or having finally ceased likewise. Furthur development consists only in thickening of zoarial parts.

Cell increase and greatest zoarial growth takes place only at the apices of the frond and margin of the basal expansion, as in *Pachydictya*. The width of any branch or part depends mainly on the relative growth vigor at the apex in the building of that part. The thickness depends a little on vigor of axial growth but mainly upon age and cell lengthening. At the same time the solid margin extends, so that some width is added to that of the first growth. The initial parts appear to have been small, narrow, dichotomously branching. Some individuals dwarfed or matured at this stage. Others grew long branches, 2 to 8^{mm} wide, dichotomous or palmate digitate. Just below the forks the zoarium is widest, and there a macula appears on medium width branches or a row of maculæ continue down the middle on wider ones, or two to four rows on palmate parts.

The cells alternate in vertical rows. They are somewhat smaller in the initial than in the later zoarial growth stages, but as a rule the widths of the zoarium correspond to numbers of cells and cell rows. Increased number of rows is less by intercalation than by marginal addition at the side of the growing apex, and decrease is by reduction at the margin. Sometimes a branch widened and narrowed repeatedly, but they usually grew uniformly for a great length. Branches are twisted, heliotropic.

This highly developed zoarium has equally modified cells. As in *Pachydictya* there is a mesial lamina or wall and the thin-walled, prostrate, short, axial parts of cells are in single series on either side, without mesopores, rectangular, or in part drawn out obliquely toward the zoarial margin. The peripheral cell part is sharply defined, both by obliquely outward direction and by a thick complex wall between autocell openings, which are thus a diameter or more apart. This wall comprises the cell walls which appear thin, and between them a mesopore space. In transverse and longitudinal thin sections one may see a tabulated mesopore followed by filled mesopore space, to which the cell walls are amalgamated on either side. What is most novel is a strong dark line or wall dividing the mesopore space. On the surface the mesopore space is elevated, rarely depressed, and the cell aperture rows are in furrows, separated by strong continuous longitudinal papillose ridges, and the apertures in each row by lower short transverse ones. The ridge may be double or again discontinuous, exceptionally. The ridges are the structural cause of the dark line or wall seen within the filled mesopore space. Maculæ have closer parallel ridges, and the zoarial solid margins may appear puncto-striate.

This structural development appears due to the chaining of zooids longitudinally, probably by a canal system which impressed the longitudinal furrows or troughs, causing the mesopore space to be relatively raised. These furrows end at the growing apices of the zoarium, where cells, respectively zooids, were increasing rapidly. As the growing apices became more remote from a given part or ceased, the furrows filled gradually, and a more allsided relation arose between the cells.

No mesopore calycals have been detected and the mesopore space being confluent with the cell calycals, and so far subordinated and fused to the autocell walls, one might conclude that the corresponding zooids or other structure was reduced to virtually an interautozooidal cortex. Comparison with *Pachydictya*, however, shows the ridges, and corresponding internal structures to be mesopore walls in origin. The so-called tubuli seen in thin section, corresponding to surface papillæ, are then modifications of mesopore walls. The autocell walls proper have none. The so-called mesial tubuli are present. The autocell may have one or two tabulæ in the peripheral region, and at the upper angle, between the axial and peripheral cell, a small hemiseptum may appear.

Similar species to the above described as to frond, compose the genus *Stictoporella*, one of which is peculiar and further instructive:

Stictoporella cribrosa Ulr.[1] is bifoliate with branches about 2^{mm} in width, which bifurcate and anastimose rapidly, growing thus to a large broad frond with numerous oval so-called fenestrules (Plate B, Figs. 7, 8, and 9). The zoarial growth from cell increase is at the branch ends, the margins of the branches, *i. e.*, around the fenestrules very quickly becoming static as to cell increase, although with age the thickening from cell lengthening extends them, constricting or even closing the fenestrules.

Normally the downward end of the initial branch is pointed with striated solid beveled surface, which is supposed to have articulated into the crater-like socket of a striated non-celluliferous basal expansion, forming a movable joint. The wide-spreading zoarial branches coalesce with other zoaria of the same and different species so freely that this joint must have been usually immovable. When part of the zoarium died out, it was regrown by a laminar cell growth, or again fragments of a zoarium grew a new one, in which case a basal expansion unlike the first was developed, or again the fragment became the basal to a lateral fenestrated sporadic growth.

Cell increase is at the growing margin from a mesial plane, as in *Pachydictya*, but the prostrate thin-walled part of the cell is long, overlapping, so that in transverse section the axial region is four instead of two cells thick. As the cells turn into the peripheral region the walls thicken and distinct mesopores intercalate. The autocell has a saucer-shaped calycal at the surface and at its center a narrow cell-opening. The small cells or mesopores are either similar, especially in young fronds, or again have the cell opening and even the calycal filled solid, in which case the autocell calycals also become ill-defined, and the surface feature is that of small cell openings and broad rounded interspaces. This condition is the maturer stage. The mesopores are either few and the autocells subquadrangular or polygonal, or again mesopores are very numerous and autocells rounded. Large or small groups of mesopores forming maculæ occur in broader parts of the branches, and the 0.5^{mm} wide border has mesopores only. A constricted, closed fenestrule simulates therefore a macula.

---

[1] This appears to be the *Clathropora flabellata* Hall!

The mesopores frequently differ in size and some of them appear to become autocells, peripheral cell increase thus existing, although necessarily to a limited degree, since the peripheral cells' length is only about equal their diameter.

Thin sections reveal no tabulæ in either autocell or mesopore. The thick walls are dense with a striping parallel to the surface calycal bottoms, *i. e.*, converging upwards to median wall. The mesopore openings are seen to constrict and close while their calycals fill, and then the increments of growth or striping cross them continuously, direct, or arched upward instead of downward across the mesopore space. In this case the amalgamation may be so complete that the appearance is that of one wall between autocell openings. This filling of the mesopore space contrasts with that of *Pachydictya* in that it is by laterally thickened vertical walls instead of by vertically thickened transverse tabulæ. Notably the results are very similar in the end.

In closed mesopore stage the zoarial margins become solid, smooth, or striated, and in the very few zoarial basal stalks seen the autocells also are filled on the surface above the beveled zoarial articulation. Ulrich describes moreover certain closing apercula over cell apertures at the bottoms of calycals, but their occurrence is sporadic, probably incidental to dying off of the zooids, since these structures never occur within the cell opening as tabulæ, which they should if the zooids survived their formation. This species has no warts upon the walls and no "tubuli."

Ptilodictya (*Escharopora*) *subrecta* Ulr. is a simple bifoliate frond, or if divided the branches do not diverge. The zoarium is sword-shaped or feather-shaped, the point or lower end articulating to a crateriform, striated basal expansion. Specimens vary from 10 to 50^{mm} long, 1 to 10^{mm} wide, and 0.5 to 1.5^{mm} thick. In fossils the basal expansion is separate from the frond, and when living they could have united by a corneous interval or the cortex alone. The frond began evidently very narrow and grew by axial, apical cell increase, the growing end widening more or less and again narrowing somewhat, according to growth vigor. Marginal cell increase near, but below the apex also occurred in some, but the older parts have a solid margin. The cells have rather short prostrate thin-walled axial part and turn more or less sharply into the peripheral direction, the walls here thickening quickly. The cells are arranged, alternating in vertical rows (Plate B, Fig 10). They are at first quadrangular, but before reaching the peripheral region become hexagonal. Here the solid interspace, or wall, thickens, so that oval or subquadrate apertures remain, these being at the bottom of calycals which are confluent in longitudinal rows, or oblique rows in case of the cells that were added marginally. Sinuous, long ridges bound the cell rows (see figure). In later growth thickening, these ridges meet alternatingly at the sinuosities bounding rhombic calycals and finally change to continuous peripheries, the cell apertures becoming meanwhile somewhat larger, subhexagonal, except in the oldest zoarial part or stem where the furrows remain.

Thin sections show the cell walls completely amalgamated, the sinuous longitudinal ridges alone being evident. No tabulæ are seen, except one or two hemisepta. But the exterior of zoaria exceptionally show a few mesopore apertures, these being in place of the furrows or again at the summit of monticules. The zoarium, if broad, is usually thickest medially, this part then having one, two, or three rows of monticules also. The thicker median part alone appears continued in the stem, which is narrow and thickened to nearly cylindrical form, tapering, ending with a beveled striated articulation area. The articulation area and supposedly the basal expansion grew *pari pasu* with the frond. In old specimens the stalk next to the articulation is solid surfaced, cell apertures having all closed over, except as to the confluent calycals or furrows.

Interpretation of this form from comparison with those described should include in the first place the suggestion that autocells which are evident are separated by completely subordinated mesopores, these being rarely evident, but really always represented in filled condition in the thick amalgamated wall. The confluence of the autocell calycals is explicable as due to the impress of a canal system which was developed strongest in vertical direction during cell increase at the apex; later an all-sided relation between zooids arising, except at the stem, where the basal expansion united. The articulation to the basal expansion shows the zoarium to have been in part non-calcareous. Again, since no pores or even "tubuli" are present, the closing up of all autocell apertures on the stem argues the cells evacuated by the zooids, except as to the calycals. The general manner of development of calycals argues the same.

The hemisepta require special mention. They have been said to have "doubtless served as supports for the movable operculum."[1] The said movable operculum is, however, unknown, and the word "doubtless" is unwarrantable. In fact, the hemisepta occur in some species beneath complete tabulæ. and in those cases they were isolated from the aperture. In *P. subrecta* no tabulæ intervene, and two interpretations may be admitted for sake of argument. The hemisepta occur one at the bottom and one at the top near the termination of the prostrate or axial cell, their position requiring no explanation except reference to some unknown particular cause if considered as accessory opercular processes. I shall add another hypothesis, viz., that they are reduced structures homologous with regular tabulæ similarly situated in other species, *e. g.*, *Pachydictya foliata* Ulr. Their position may be accounted for as related to the sharp turning of the zooid and its cell from axial to peripheral direction, and thus may be taken as evidence that the zooid evacuated the cell as it built. (See text Fig. 2, *A*, p. 169.)

---

[1] Vide Text-Book of Palæontology, by C. R. EASTMAN, Vol. I, p. 279, l. 4.

Some smaller closely related species (*Arthropora*) are many-jointed, partly simulating, therefore, the following one. Very probably some cylindrical forms like this one should be considered as to origin as narrow bifoliate, and hence having become rounded.

Arthroclema armatum Ulr. consists of numerous small celluliferous jointed segments which formed a branched zoarium. Numerous primary segments form the main stem, from which lateral branches arise, these being composed of many secondary segments and bearing likewise lateral branches of tertiary segments. These hundreds of segments are each about 3^{mm} long, subcylindrical with generally six or five or four rows of cell apertures, six to ten apertures in a row. The primary segments are 1^{mm} or less in diameter, the others 0.5 and 0.3^{mm} or less.

Each primary segment has a small axial region in which the cells are prostrate, thin-walled, and angular, and a peripheral region which is thickened according to age. The small, rounded cell apertures are separated by solid, longitudinally furrowed interspace and a large prominence behind each aperture. Some of the apertures are closed by constriction near the articulation areas. The ends or articulation surfaces are solid-faced, respectively concave and convex, and the lateral articular socket, when present on a segment, is impressed in the peripheral solid wall. Thin section shows the walls thoroughly amalgamated, the peripheral region merely having striation parallel to the surface.

Secondary and tertiary segments are similar to primary ones partly developed.

A related genus, *Arthrostylus*, has the segments with four sides, one of which is without cell apertures but striated.

Rhombopora lepidendroides Meek. is strictly a cylindrical type. A small, thin basal expansion supports a long, branching, cylindrical stem about 2^{mm} in diameter. There is a central thin-walled axial region in which the polygonal cells may have one tabula, and there is a narrow, thick-walled peripheral region with narrow cell openings without tabulæ. The surface shows oval cell apertures at the center of calycals, these being arranged in transverse, vertical, and oblique rows, their margins being more or less in contact. The elevated interspace has rows of small warts, which divide the zoarial surface somewhat into rhombs, including each a calycal. Usually a second larger set of warts or acanthopores are situated at the junction of the rows. The internal wall structure corresponds, *i. e.*, the thin, dense walls of the axial region change quickly to thick in the peripheral region, with striation parallel to the calycal, interspace, and wart surfaces.

There is no distinct evidence of mesopores, but a simulation of maculæ and other characters in common with the forms of Trepostomata, genera *Batostomella*, *Eridotrypa Batostoma*, which they approach more closely than to other than cylindrical Cryptostomata, would indicate that the interspaces are mesopores rather than thickened autocell walls alone.

Phylloporina corticosa Ulr. belongs to the reticulate series, and has a reticulate frond and solid basal expansion (Plate B, Figs. 11 and 12). The frond is composed of so-called branches 0.5 to 1 or 2^{mm} wide, which anastimose laterally at somewhat regular intervals, producing elongate fenestrules. Each branch has cells on the obverse side, but none on the solid, smooth or striated reverse side. Thin sections show that the cells arise mesially, have a long, thin-walled, tabulated prostrate portion, then become more closely tabulated as they turn slowly into the peripheral region. The axial cells overlap so as to be three or more deep in transverse section. The peripheral region is characterized by filled interspaces or mesopores which more or less completely separate the cells, the cell margins rising a little above the interspace at the surface. Zoarial growth as to cell increase took place only axially, *i. e.*, at the branch ends. The peripheral growth comprised thickening of the branches with cell lengthening on the obverse side and with about equally as thick, solid or rarely vesiculose increment on the reverse side, thus proving the branch to have been surrounded by a secreting cortex. Young branches usually have on the obverse a median keel, the edge of a wall or walls extending from the mesial line, and this E. O. Ulrich compares to the longitudinal ridges dividing cell rows in *Rhinidictya*. It bears a few acanthopores. An obtuse keel on the reverse produces no internal wall distinction. With age the keels disappear from the then rounded or flattened obverse and reverse sides, and the fenestrules constrict, even closing some of them. Branches are 1 to 2^{mm} thick.

The cell apertures are arranged in one or two rows on each side of the median keel, or a few more at inosculations.

The basal expansion is the key to the better understanding of this zoarium. To the description of it as "an expanded base," the following is added from specimens at hand: Basal expansion thin, incrusting, about 2 or 3^{cm} in diameter, the marginal or younger part bearing stellate monticules like those of *Stellipora* (*Constellaria*), *i. e.*, a central depressed macula with six to twelve rays, between which are as many sloping ridges of autocells. These monticules or stars are about 3^{mm} in diameter. The rest of the expansion is crowded with young stars between larger older ones of various sizes. It appears that the stars increase in size by addition of a few ridges, all of the ridges elevating rapidly at their proximate ends. When about 1^{mm} high they begin to anastimose, and they continue to grow and elongate upward, anastimosing and branching, whence arises the reticulate funnel-shaped frond, with cell apertures turned to the outside and a solid, striate surface on the inner side; the obverse side of the branches arising from the celluliferous ridges of the monticule, the reverse solid surface continuing from the central macula, which has become solid or coarsely vesiculose, succeeding distinct mesopores, and forms the bottom of the funnel. The median keel of the obverse side is, again, the continuation of that of the ridge in the monticule stage, the same as appears in the ridges of stars on *Stellipora.* The arrangement of the cells on the branches originated likewise in that of the stars. The basal expansion bears one largest frond, two to five smaller ones, and several monticules of various degrees. The internal structure of the basal is more similar to *Stellipora* than to that of the frond or reticulate part of *Phylloporina.*

The grown funnels must have crowded each other, and in fact fossils evince irregular shape in their later stages. Some evidently met accident, since specimens occur in which a new growth arises from the broken edge of an older piece and in a new direction. Also, a secondary basal lamina may develop from the poriferous side of a fragment, bearing new somewhat regular stars or monticules. A fragment may convert itself into a single large monticule or new basal, and other variations occur.

The long cells with many tabulæ in *Phylloporina* are remarkably like those of Trepostomata. The basal expansion like a *Stellipora* and the development of the reticulate funnels from monticules suggests relationship with Trepostomata and not with bifoliate Cryptostomata. There is not then any relation between the *Stictoporella cribrosa* type of anastimosing branches and the similarly anastimosing parts of *Phylloporina*, which might better be called bars than branches to distinguish them.

Other truly reticulate forms probably derived from *Phylloporina* as E. O. Ulrich suggests.[1]

Septopora biserialis (Swal.) has branches or bars 0.8 to 0.3^{mm} wide, dividing laterally, and united at intervals by transverse processes called dissepiments, rather than anastimosing, the whole forming a fenestrated frond with primary branches or bars arising from an irregular basal attachment, and from these a little narrower, parallel to slightly radiating ones. The fenestrules are rather wider than the bars; ten bars occur in 1^{cm}. They have celluliferous obverse side and solid reverse, the latter on the outer or under side of the zoarium and forming the basal expansion and sometimes rootlike anchors at intervals above it. From the base a more or less funnel-shaped stalk supports the large frond on one side.

---

[1] EASTMAN, op. cit., p. 281.

The cell apertures are about 0.13^{mm} in diameter and on the bars are arranged in two rows, separated by a thin median ridge which bears more or less prominent small warts or acanthopores. The dissepiments have distributed cell apertures only.

The internal structure seen by thin sections consists of short prostrate thin-walled axial cells arising mesially, turning sharply into the peripheral region where they become surrounded by interstitial solid deposit. Thus the cells have the appearance of being thin walled "enclosed in a calcareous crust," since the mesopore spaces on the obverse and the equally thick solid deposit on the reverse, surround the cells. There is a median wall or structure corresponding to the median ridge. The reverse is longitudinally striated at first, later nearly smooth, and its internal structure corresponds thereto. Further, it has been claimed that the solid deposit on the obverse and reverse had small vertical pores ending in minute warts at the surface, but that the dim structures so interpreted were open tubes may well be doubted. Another feature, the so-called dimorphic pores (cells), arise in the solid deposit of the reverse and obverse, are somewhat smaller than the regular cells but at the surface end with slightly elevated peristome like these. They are not to be wondered at, since they arise in what is homologous to mesopore space in, for example *Stellipora* or *Stictoporella*, and may be taken as evidence that peripheral cell increase had not wholly disappeared. The cells have no tabulæ, but sometimes a hemiseptum.

The dissepiments in this zoarium are comparable both to drawn out inosculations from which they may have arisen and to side branches to which they are tending. The relation of obverse and reverse of the frond is a little strange, since they are reversed as compared to *Phylloporina*, the basal expansion also being unlike in that genus; differences which I cannot explain, but yet are of small import since closely related genera as *Fenestella* and *Semicosmium* differ in just that way. I feel not assured that the primary basal expansion is known except in *Phyllopornia corticosa* Ulr.

DISCUSSION OF CRYPTOSTOMATA.

These described species may suffice to represent the Cryptostomata. The species of *Pachydictya* and *Rhinidictya* are of the Rhinidictyonidæ; *Stictoporella* and *Ptilodictya* of the Ptilodictyonidæ; nothing especially different is seen in the Cystodictyonidæ except sometimes a lunarium like that in the Trepostomata; *Rhombopora* is of the Rhabdomesodontidæ; *Arthroclema* of Arthrostylidæ; *Phylloporina* of Phylloporinidæ; *Septopora* of Acanthocladiidæ; and the Fenestellidæ are merely distinguished from the latter by having dissepiments without cell apertures on them. In these all, and those which they are taken to represent, the growth is acrogene and cell increase is almost all axial. Axial and peripheral regions are sharply defined, cells short, and mesopores filled more or less solid.

The Cryptostomata differ in degree of specialization of structures rather than in kind from the Trepostomata. In fact, they are arbitrarily divided in all respects. The defined axial and peripheral regions of zoarium appearing to arise in Trepostomata are merely as strongly to stronger developed in Cryptostomata. So also are the long, tabulated cells changing to shorter, with or without tabulæ and so-called hemiphrams or hemisepta. Peripheral cell increase is only reduced to nearer the minimum. The mesopores begun apparently as young cells in Trepostomata and developing to subordinate special structures or vesiculose to solid interstitial filling, are vesiculose to solid in Cryptostomata. Monticules ranging to the extreme from called maculæ in the former are represented by maculæ in the latter. Indeed, sharply defined peripheral region, short cells, reduction of tabulæ, hemiphrams, filled vesiculose or solid mesopores, and solid maculæ, so-called acanthopores, and mesial lamina, lunarium, etc., are found in highly specialized Trepostomata of the Fistuliporoid type.

There is no character in Cryptostomata that distinguishes them all from Trepostomata. The former comprises essentially certain families of highly modified zoaria related to Fistuliporidæ of Trepostomata. They are not a single branch from these, but three or more, as seen when examples like *Pachydictya*, *Rhombopora*, and *Phylloporina* are compared. The genera named are the Cryptostomata, which are scarcely separable, if at all, from Trepostomata, but are not related one to the other as closely as to Trepostomata. They compare back to *Cramophylla*, *Eridotrypa* and *Stellipora* respectively, which belong to three different recognized families of *Trepostomata*. They belong to more than distinct families, to three divisions of Cryptostomata, the frondiferous, cylindrical, and reticulate respectively. The highest differentiated Cryptostomata, also, for example, *Ptilodictya* and *Fenestella* unite to not the same Trepostomata-like Cryptostomata. The question should be rather on the propriety of dividing the Monticuliporoidea at all than on the probability of Cryptostomata and Trepostomata belonging to different phyla.

As to the interpretation of the zoarium of Cryptostomata, the entire skeleton, excepting the under side of the basal expansion, was covered by some kind of cortex uniting the zooids, as proved by deposits of superimposed laminæ in intercellular spaces, on solid margins, and on the reverse surfaces. The zooids built and evacuated the cells, resting more upon than in them at maturity, as proved by tabulæ close to the aperture, by closed-up autocells, as in the stem of bifoliate zoaria, and by the building of skeleton exclusively at its outer surface. Subordinated zooids, in some degree of development, were always present, since mesopore spaces, distinct or filled, are always present in the peripheral region. Solid maculæ, solid zoarial margins, and solid obverse of reticulate ones are mesopore areas being seen sometimes as such (*e.g.*, *Stictoporella*, *Phylloporina pars*, *Semicosmium*), and are probably all really maculæ covered by subordinated zooids, or at least a cortex. Longitudinal median ridges and walls arise variously. Again, in jointed forms (*Ptilodictya*, *Arthropora*, *et al.*) part of the skeleton was not calcareous. These show reduction from the entirely calcified zoarium, and also the filling up of mesopores and some autocells might be readily interpreted as due to leveling down of division walls between zooids: a process of reducing thin-walled cell mass to a solid axis within a living cortex.

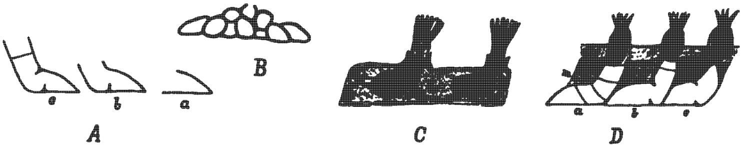
A quite different interpretation from that just given is expressed in the current definitions of Cryptostomata. Vine[1] defined them, "Zoœcia tubular, subtubular, in section slightly angular. Orifice of cell surrounded by vestibule, concealed." He does not speak of tabulæ, mesopores, acanthopores, etc., and only later knowledge, especially by E. O. Ulrich, has changed the definition, adding to *vestibule*, "which may be intersected by straight diaphrams or hemisepta owing to superimposition of layers of polypides," "surrounded by vesicular tissue or solid calcareous deposit." Vine, having in mind such as *Septopora* and *Ptilodictya* without tabulæ, seems to consider the cell as a permanently occupied zoœcium; Ulrich includes the richly tabulated *Pachydictya*, *Phylloporina*, etc., and speaks therefore of superimposition of polypides or zoœcia. More direct interpretation would indicate each cell to have been gradually built and evacuated by one zooid, as argued in the preceding pages. For corresponding explanation of hemisepta see text, p. 161.

The separation of Cryptostomata from Trepostomata is scarcely tenable, and they may be discussed together. The zoarium of Cryptostomata is merely the more differentiated, the simplest Trepostomata and the typical Cryptostomata being extremes in the same line. This developmental series might well be compared to the reduction of thin-celled Tabulate corals to a solid axis,[1] details of which may be omitted here, since there is no character in Cryptostomata as also in Trepostomata negative to supposed relation of Monticuliporoidea to Tabulate corals as already discussed, unless, as said, their relation to Bryozoa can be proved.

---

[1] Brit. Assn. Rep., 1883, p. 184.

In comparing to Cylostomata to which Cryptostomata have been sometimes referred, *Stomatapora* and *Berenicea* come first into consideration. Vine referred them to Cryptostomata in fact. These genera comprise essentially the Paleozoic Cyclostomata, and range from Ordovician to Recent times. *Stomatopora* (*e. g.*, *S. inflata* H.) forms branching single series of club-shaped prostrate free cells, each arising from under the anterior, larger end of the preceding one, and having a small circular aperture on the anterior upper side. Its walls are said to be minutely porous if well preserved. *Stomatopora* is not comparable to any of the Monticuliporoidea, but is a key to species called *Proboscina* or *Berenicea*.



AFFINITIES OF MONTICULIPOROIDEA.

FIG. 2. Diagrams showing: *A*. Interpreted origin of inferior and superior hemiseptum. *a*, axial cell stage; *b*, turning stage; *c*, peripheral stage, hemisepta remaining at points where the relation of zooid and its cell changed most. *B*. *Proboscina minnesotensis* Ulr., transverse section. × 40. *C*. Relation of zooids of Bryozoa to their cells, for comparison with *D*, the interpreted relation in Cryptostomata. *a*, tabulated cell as in *Pachydictya;* *b*, cell with hemisepta as in *Ptilodictya;* *c*, cell closed by wall-thickening as in same.

Proboscina minnesotensis (Ulr.) forms two, three, or more series of prostrate cells, each arising from under the anterior of the preceding cell of its series. The anterior end is drawn out upwards, making a vestibule, as it is called, bearing the round aperture. The cells appear superficially as immersed in a band of stereom, but thin sections show only compacted, thin-walled cells (text Fig. 2, *B*), the alternating apertural ends being rounded, the other cells at that point being appressed, angular. The walls are poorly preserved as compared to fossil brachiopods and corals upon which they have grown, but very probably the basal side of the cell only was porous. Sometimes the bands or branches become very wide, thus approaching nearly *Berenicea* proper, in which perigene growth, like that of incrusting monticuliporoids is simulated. Since *Stomatopora* and *Berenicea* include also Recent species, their position as Bryozoa is established. The serial relation of other Cyclostomata and the rather similar zoaria of Chilostomata are further well shown in handbooks, and will not be discussed here.

---

[1] *Pachypora*, *Corallium*, etc., see Neues Jarb., Beilb. X, p. 306–312.

In comparing *Berenicea*, including *Proboscina*, one at once notes that there are no tabulæ, no monticules or maculæ, no mesopores, no thick walled region, that the apertural vestibules are free and cell walls perforate. Monticuliporoid cells have imperforate walls. Further, all monomorphic monticuliporoids are again different, having without exception apertures of cells crowded together. Dimorphic forms with tabulæ are also to be excluded, while dimorphic, short celled, non-tabulate forms may be admitted to closer comparison. In fact, such as *Protocrasina* (Eastman, *op. cit.*, p. 262, Fig. 417) appears to be, might be bryozoon or monticuliporoid as to its outward aspect, the nature of its walls as poriferous, thin, or dense, thick, being the determining difference. But the comparison requires the Cyclostomata to be viewed as derived from highest specialized Monticuliporoidea, the dense autocell walls of these to be explained as having become porous in *Berenicea*, *et. al.*, and the thick, solid mesopore spaces reduced to a minimum, and thus at once a weak chain of hypotheses or an arbitrary definition is required to unite the nearest Bryozoon, *Berenicea*, to Monticuliporoidea.

Other Cyclostomata differing from *Berenicea* in changing the prostrate growth into bifoliate, acrogene, or massive form, and the cell apertures and vestibules from free to more or less in contact as in *Osculipora*, *Aspendisia*, etc. (Eastman, *op. cit.*, pp. 264–265), resemble thereby such monticuliporoids as *Stellipora*, *Septopora*, etc., but only superficially. The Cerioporidæ (*op. cit.*, p. 266) most resembling Trepostomata have porous walls and are in the second place not well determined. If viewed as derived from Trepostomata the walls being assumed as having become porous—an admissible hypothesis—this hypothesis requires a reverse view of the evolution of Cyclostomata from the first one, *i. e.*, that the long tabulated cell, not the short open one, is the more primitive in Bryozoa.

The same differences disunite Chilostomata as Cyclostomata from the Monticuliporoidea, where also their outward appearance is similar, as for example *Retopora* (*op. cit.*, p. 289) and *Septopora*.

The greatest importance rests on the interpretation of the zooid's position with reference to the cell. In Bryozoa the zöoid inhabits closely the cell. In order to refer Monticuliporoidea to Bryozoa it appears essential that the zooid be considered as occupying the cell and Vine has so interpreted in his definition of Cryptostomata, as said. In cells without tabulæ of some species the interpretation might appear logical (*e. g.*, *Ptilodictya*, except on the stem) but other species have tabulæ (*e. g.*, *Phylloporina*), whence the interpretation of superimposition of zoœcia and of zooids. This interpretation then unfortunately assumes that which most requires proof. If there is anything clear in Monticuliporoidea it is that the cell is the unit structurally in every zoarium, that loculi between successive tabulæ can not be coördinated as such units because of inconstancy alone. They vary in length and breadth ratio from 1 × 10 to 10 × 1 and more, in the same zoarium. The interpretation of loculi as zoœcia precludes all uniformity of size and shape of zoœcium. In fact, the loculi are not described as structurally units in any species—but the cell. In the definition of orders only the successive loculi have been called zoœcia, an interpretation that is simply not supported by any evidence from the zoarial structure.

Interpreting the cell, not its loculi, as the zoœcium a great difference is at once evident between Bryozoa (text Fig. 2, *C*) and Cryptostomasa (Fig. 2, *D*) and Monticuliporoidea in general in the position of the zooid—a matter of greater importance than tabulæ, hemisepta, acanthopores, communication pores, etc. Moreover, tabulæ characterize the Monticuliporoidea and true pores the Bryozoa. One cannot assert that no bryozoons have tabulæ but they probably do not. The superimposition of cells frequently occurs in monticuliporoids and in bryozoons, but forms a recognizably distinct structure from that of the tabulated cell proper. One finds, again, many descriptions of pores in Monticuliporoidea but none recognizably like those in Bryozoa, which run direct, transverse, through the cell wall as communication pores. The supposed pores parallel the cell walls and do not end in the cell, and if they were demonstrably pores, their difference would rather serve to separate the group from true Bryozoa. They are not pores in most cases. In case of the reticulate cryptostomata one might not wish to deny that pores could exist, but yet their existence is notably only in the mesopore space or outside the autocell wall, and might be interpreted like the minute porousness of some corals (Tubipora) due to living cells remaining in the stereom, rather than as canals.

SUMMARY

Briefly reviewed the Monticuliporoid zoarium consists, in the first instance of monomorphic tabulated cells, differing from the extinct *Chaetetes* corals in the cell increase being less often by fission than budding. In the second instance, the young closely tabulated cells develop with a retarded or mesopore stage preceding full size growth. In the third, many cells appear to be permanently mesopores, autocells however arising from mesopores. Some autocells displace several mesopores in their rapid growth expansion and the mesopores are either distinct or their bounding walls imperfect and tabulæ vesiculose. This development and its minor features is paralleled in living and fossil Alcyonarian Tabulate compound celled corals. In the fourth instance the cells are shortened, and the mesopores or interstitial space filled solid either by superimposed tabulæ or by thickened bounding walls: cells with few or no tabulæ or filled: Cryptostomata.

There is an accompanying differentiation from uniformity in the first instance to marked axial and peripheral region of the cell in the fourth and other characters incidental therewith. But all things considered the monticules and their special form maculæ, are all that separate the Monticuliporoidea from other Tabulate (Alcyonarin) corals, but apparently not from certain living Alcyonaria, which have possibly descended from them.

As to Bryozoa, two hypothetical comparisons with Monticuliporoidea are to be considered. First, the Cerioporidæ including *Heteropora*, may be Bryozoa derived from Monticuliporoidea in the first instance just mentioned, the solid wall having become porous with transverse canals. Secondly, Berenicea and other Bryozoons with more or less free vestibules might have derived from the fourth instance, being then a fifth stage or instance, the mesopore solid filling having reduced to nothing and imperforate cells walls having become perforate.

The Monticuliporoidea are difficult to separate from corals in two concordant instances. In two instances in which their structures nearest approach the Bryozoa, they separate easily or rather are difficult to unite with them, and of these instances the one probably negatives the other.

EXPLANATION OF PLATE B.

FIG. 1. Pachydictya foliata, frond natural size.

FIG. 2. Pachydictya foliata, longitudinal section. × 10.

FIG. 3. Pachydictya foliata, tangential section. × 10, showing cell pattern.

FIG. 4. Rhinidictya mutabilis, frond of an undersized individual.

FIG. 5. Rhinidictya mutabilis, part of surface. × 20, after Ulrich.

FIG. 6. Rhinidictya mutabilis, longitudinal section. × 10.

FIG. 7. Stictoporella cribrosa, lower part of frond with articulation.

FIG. 8. Stictoporella cribrosa, surface. × 20.

FIG. 9. Stictoporella cribrosa, longitudinal section. × 20.

FIG. 10. Ptilodictya subrecta, surface. × 20 showing zoarial margin.

FIG. 11. Phylloporina corticosa, part of basal expansion and one frond. × 2.

FIG. 12. Phylloporina corticosa, longitudinal section. × 20.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.,
November 5, 1900.

STUDIES FOR STUDENTS

THE STRUCTURE OF METEORITES. II.

(Continued from page 66)

CHONDRITIC STRUCTURE

This characterizes the great majority of stony meteorites, and being peculiar to meteorites will be described in detail. Of the 314 stone meteorites listed by Wülfing in his recent classification, 288 are more or less largely composed of chondri. Some meteorites are composed of chondri almost exclusively (Borkut) while others contain them imbedded in a groundmass. The latter may be tuffaceous, glassy or crystalline. The term chondrus, plural chondri, is from the Greek χόνδρος, a grain, the term being applied in reference to the size and shape of the body. Some writers prefer the diminutive form of the word, viz.: chondrules. In size chondri may vary from that of a walnut to a dust-like minuteness. The larger number are about the size of millet seeds. The form of chondri is generally spheroidal, but varies from essentially spherical to mere irregular fragments. Some chondri are flattened or oval and others show apparent deformation subsequent to their origin. In the latter, depressions or projections occur which often look as if a hard chondrus had pressed against another soft one during the process of formation. The deformed chondri pass by every gradation into those which appear to be rock fragments with rounded angles. The surface of the chondrus is rarely smooth, being usually rough or knobbed. From many friable meteorites individual chondri can easily be isolated, but if the meteorite is at all coherent the chondri break with the rest of the mass. The color of chondri is usually white or gray, but some are brown to black. As they are often of the same ingredients as the groundmass in which they are imbedded they may differ little in color from it. On this account and on account of an ill-defined contour they may be overlooked and a crystal may be considered porphyritic, which is really part of a chondrus. Usually, however, the chondri are plainly marked on a polished section by differences in color and contour. In structure chondri may themselves be granular, porphyritic, coarsely or finely fibrous. They may consist of a single crystal individual, in which case they are said to be monosomatic, or of several individuals, when they are said to be polysomatic.

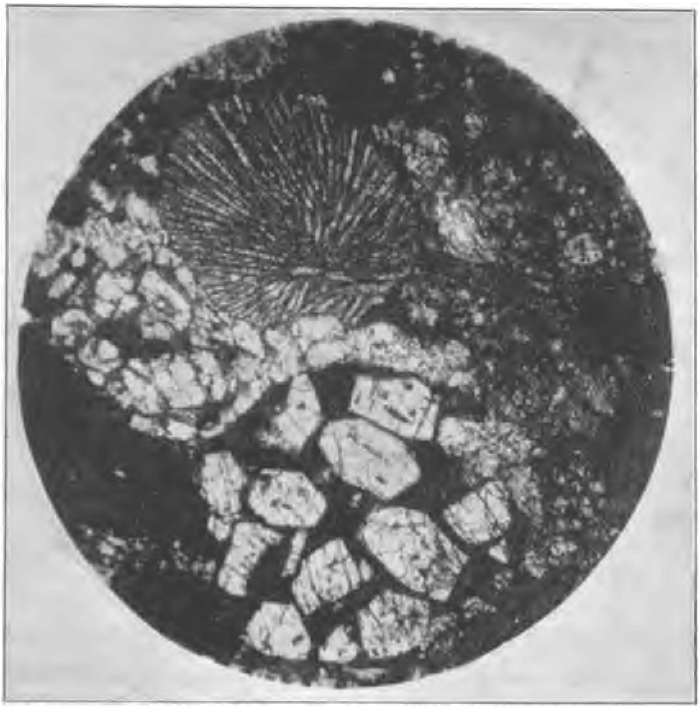


Fig. 7.—Section of the Homestead meteorite, showing a typical eccentrically-radiating bronzite chondrus (above) and a porphyritic chrysolite chondrus (below). A granular chrysolite chondrus also appears at the left. × 65. After Tschermak.[1]

---

[1] Die mikroskopische Beschaffenheit der Meteoriten. Tafel VII, Fig. 4. Figs. 2, 3, 4 and 5 of Article I should also be credited to Tschermak, Lehrbuch der Mineralogie, 4th edition, p. 585.

True monosomatic chondri are confined almost exclusively to the mineral chrysolite. They can be known by their simultaneous extinction in polarized light. Polysomatic chondri may be made up of different minerals as well as different individuals and may show more than one kind of structure, *i. e.*, a chondrus may be granular in one portion and fibrous in another. The following minerals are noted by Tschermak as forming chondri, their relative abundance being in the order named: Chrysolite, bronzite augite, plagioclase, glass, and nickel-iron. This order, it is to be noted, is also that of the fusibility of the minerals, the most infusible and hence the earliest cooling mineral forming the most chondri. Chrysolite chondri usually contain large quantities of glass of a dark brown color. This may be arranged (*a*) in the form of alternating layers, in which case a marked rod-like or lamelliform appearance is produced, or (*b*) may form a base in which the mineral is developed porphyritically, or (*c*) may occur in the center of a crystal, or (*d*) may form a network. Polysomatic chondri of the latter sort are especially liable to be mistaken for those of bronzite since they simulate the fibrous appearance of the latter. Occasionally the crystallization may have proceeded only far enough to produce skeletal or branching growths of the mineral among the glass. Both monosomatic and polysomatic chrysolite chondri may have the arrangement of a well-marked rim about a spherical interior. This rim may, in the polysomatic chondri, be composed of many individuals. Such a rim is often dark from a content of iron and troilite. Chromite, either in minute grains or in dust-like aggregations, also forms a common inclusion usually near the surface of the chondrus. The quantity of opaque inclusions may be so great as to give the chondrus a black color. Such chondri associated with those of light color are to be found in the stones of Knyahinya, Mezo-Madaras and others. The constituent minerals of such chondri are chiefly chrysolite and bronzite. Bronzite chondri are usually of a finely fibrous character. The fibers instead of radiating from a center as do those of spherulites usually radiate from an eccentric point. This eccentric arrangement constitutes one of the most marked features of the chondri and separates them sharply from any formation seen in terrestrial rocks. The bronzite chondri have less glass than those of chrysolite. Monosomatic chondri of bronzite have never been observed, the large

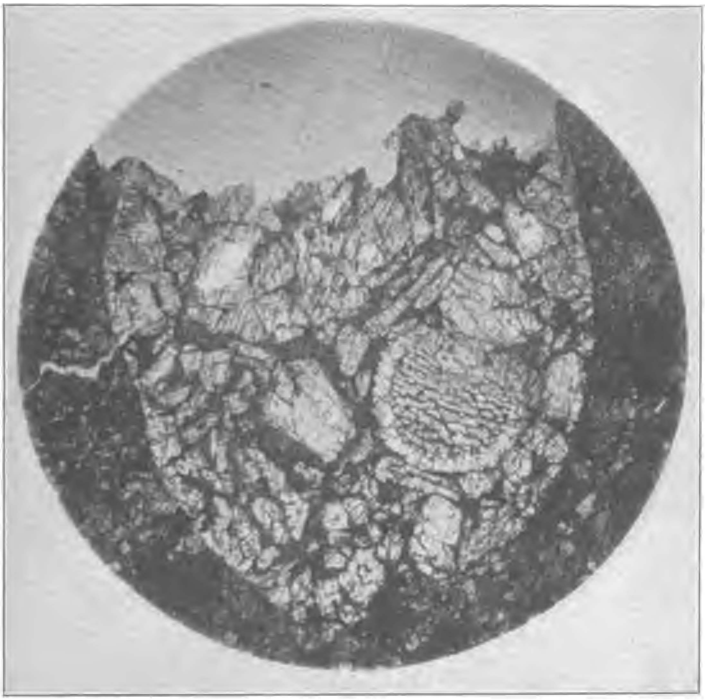


FIG. 8.—Section of the Dhurmsala meteorite, showing a large, somewhat porphyritic chondrus enclosing a smaller monosomatic one. Both are composed of chrysolite. × 8. After Tschermak.[1]

crystal individuals showing, as a rule, no tendency to a spherical form. Besides bronzite chondri having an eccentric arrangement of fibers there occur those which are confusedly fibrous, and these may pass into those which have a netted appearace from crossing fibers. Such chondri, cut at right angles to the fibers, show the fibers to have a concentric arrangement. The chondri already mentioned, which are granular in part and in part fibrous, are usually made up of the two minerals chrysolite and bronzite. These minerals may be present in about equal quantity or either may be in excess. Usually the bronzite together with glass appears to occupy the intervening spaces between the chrysolite grains, indicating that it is of later formation. Augite chondri are not common but occasionally occur. They often show a structure which indicates repeated twinning. The mineral may appear also in the form of grains, usually of a green color. These grains can be distinguished from chrysolite by their behavior in polarized light. Chondri containing plagioclase in any large quantity are also rare but have been observed by Tschermak in the stone of Dhurmsala. The plagioclase alternates in bands with chrysolite and is in excess. Chondri also occur which are composed almost exclusively of glass, the only indication of the presence of other minerals being in the presence of forked microlites which may be referred to bronzite. Occasionally these microlites are of a pronounced star-like form. Chondri, or at least rounded spheres of nickel-iron, occur in some meteorites, though they are not common. All gradations occur from chondri which contain grains of nickel-iron to complete spheres of nickel-iron. In the stone of Renazzo such spheres have a covering of brown glass. Some of the spheres or rounded fragments also contain troilite, but troilite of itself never has been seen to form chondri. A more or less complete rim of metal is a characteristic of many chondri. The metal may occur in the form of rounded grains or as a continuous periphery. It has been suggested by Daubrée that such a rim shows that the chondrus has been subject to the reducing action of hydrogen. Besides the chondri colored black by inclusions of iron and troilite, as previously described, black chondri, which consist chiefly of maskelynite or granular plagioclase, occur in the stones of Alfianello, Chateau Renard and others. These chondri are transparent and colorless about their rim, but in the interior are totally black from inclusions of angular rounded grains, some of which are shown by their brown color to be troilite. A gathering of grains at the center distinguishes these chondri from those previously described in which the rim was black. Besides complete chondri, fragments representing various proportions of a complete chondrus occur. These may, on account of their shape, be very misleading, as they may be taken for porphyritic individuals or for portions of a foreign stone if their previous chondritic origin is not recognized. Tschermak states that fragments of chondri are most numerous in the stones whose chondri have well-marked contours. So far as the association of chondri is concerned it is to be noted that chondri of more

---

[1] Op. cit. Tafel VIII, Fig. 1.

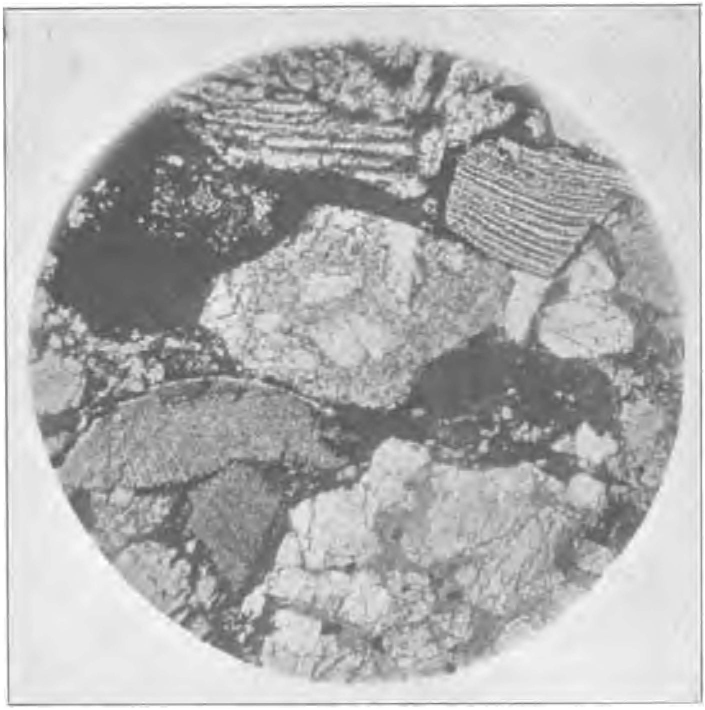


FIG. 9.—Section of the Mezo-Madaras meteorite, showing a meteoritic tuff made up of fragments of chondri. Portions of bronzite, chrysolite and nickel-iron chondri can be recognized. After Tschermak.[1]

---

[1] Op. cit. Tafel XIX, Fig. 4.

than one of the kinds above described usually occur promiscuously scattered through the same stone. There is no gathering of them into groups according to the minerals they contain. Occasionally one chondrus encloses another, and still more rarely two may be joined together. Broken fragments of chondri commonly occur in the same stone with complete chondri. Two fragments of the same chondrus are, however, rarely if ever found in juxtaposition. Hence there must have been considerable separation of the fragments before consolidation of the stone took place.

Theories of the Origin of Chondri and Chondritic Structures.--The conditions which have brought about the formation of chondri are not well understood, though the question has been much discussed and various hypotheses have been suggested. The views of earlier observers were to the effect that the chondri represented fragments of preëxisting rock which, by oscillation and consequent attrition, obtained a spherical form. Sorby regarded them as produced by cooling and aggregation of minute drops of melted stony matter. Tschermak considers their origin similar to that of the spherules met with in volcanic tuffs which owe their form to prolonged explosive activity in a volcanic throat breaking up the older rocks and rounding the particles by constant attrition.

Different views are, however, held by Brezina, Wadsworth, and others, these believing that the chondri have been produced by rapid and arrested crystallization in a molten mass.

Objections to theories of the first class are to be found (1) in the fact that the chondri usually have rough-knobbed surfaces instead of smooth ones, such as attrition might be expected to produce; (2) in the regularly eccentric form of most enstatite chondri, which attrition would be likely to destroy; and (3) in the fact that fragments of a preëxisting rock ought to show the constitution of the rock as a whole instead of specialized structure. Objections to theories of the second class are to be found chiefly in the clearly fragmental nature of most chondritic meteorites. It is in their variation from the surrounding ground mass and in the eccentric arrangement of their fibers that chondri differ chiefly from the spherulites of terrestrial rocks.

SUPERINDUCED STRUCTURES

Several structures occur in meteorites which have apparently originated subsequent to the consolidation and solidification of the mass as a whole. These may be enumerated as (1) slickensides, (2) faults, (3), bent plates, (4) veins, and (5) cleavage and joints. The first three may be grouped under the head of evidences of preterrestrial movement, but it should be stated that some authorities regard all these structures, including veins, as of terrestrial origin.

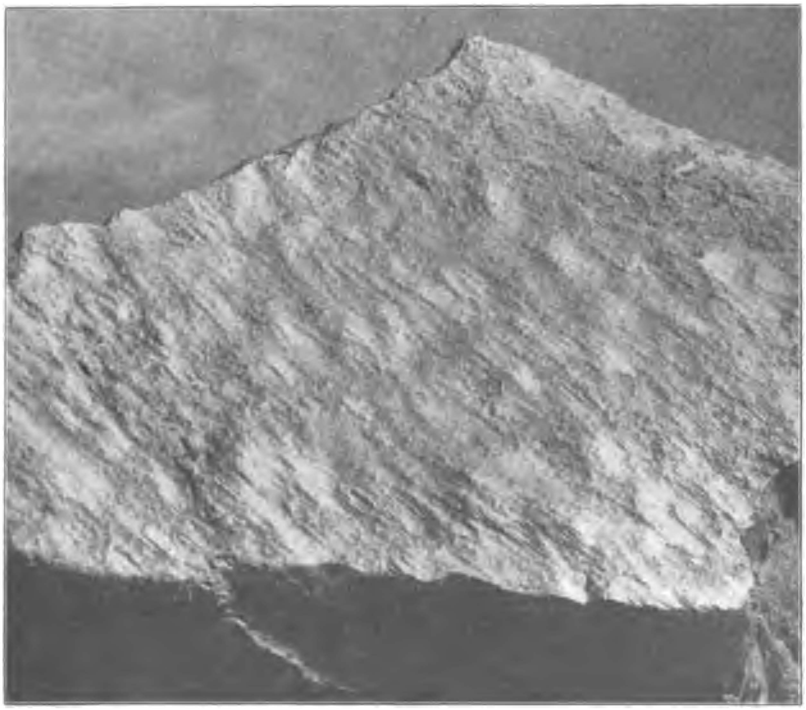


FIG. 10.—Slickensided surface, Long Island meteorite. Natural size. From a specimen in the Field Columbian Museum.

Slickensides (*Harnisch flachen, Surfaces de frottement.*)—These may be observed on portions of many meteorites, of which the following may be mentioned among others: Bath, Kesen, Limerick, Lixna, Long Island, Manbhoom, Mocs, Ochansk, Ställdalen, Tysnes Island, and Zavid. The slickensided surfaces may vary in area from a few square millimeters to those more than a foot square (Long Island). In many cases the surfaces have exactly the appearance of similar ones in terrestrial rocks, being smooth, shining, somewhat uneven, and more or less striated in the direction of movement. In other cases, however, they appear as dark striations on the contact surfaces, or as if the surfaces had been rubbed with a piece of graphite. The slickensided surface may be a broad peneplane with generally parallel striae, or it may be seen penetrating the meteorite in numerous narrow peneplanes following the same general directon at different levels. The surfaces do not always extend in the same direction, however, but in different directions and occasionally nearly at right angles to one another. One surface on the Long Island meteorite has in cross section the shape of a J. The polishing of the surface by the movement which has taken place often brightens the metallic grains so that they shine. Sections cut perpendicular to a slickensided surface show a flattening or elongation of the metallic grains, and even of other minerals along the course of movement,

Meunier regards the blackening seen on the surfaces as indicating heat developed by the movement, and states that the heat was sufficient to metamorphose a portion of the Mexico meteorite included between two slickensided surfaces, which he examined. The slickensided surfaces examined by the writer, however, give no evidence that the movement has been accompanied by any high degree of heat, at least enough to produce fusion, for the mineral grains along the surface are simply sharply cut off without alteration. This fact, together with the analogies given by terrestrial slickensides, indicate that the movements which gave rise to the slickensides must have taken place while the constituents of the rock were solid.

Faults.—Evidence of movement along a plane sufficient to produce well-marked faults in meteorites is not abundant. The slickensides already described prove slight movement, but how much, so far as the stony meteorites are concerned, it is difficult to say on account of the absence of bedding planes and other criteria of measurement. In the iron meteorites, however, the bands of the Widmanstätten figures afford a means of measurement. Sections of several such meteorites, viz., Bridgewater, Carlton, Magura, Puquios, and Descubridora, in this way exhibit faulting. In the Puquios meteorite the faulting is of somewhat complicated character, the kamacite bands showing slight dislocation in various directions. The largest fault extends the entire length of the mass, and has a throw of ⅛ of an inch (3 mm). Some crushing and branching also appears along this line of faulting. Other less extensive lines of faulting occur. The amount of throw seen in the Descubridora meteorite is more extensive than in the Puquios, being a distance of from ¼ to ½ an inch (6 to 12 mm). Owing to the toughness and tenacity of iron meteorites at ordinary temperatures, Howell has suggested that such faulting could only have been produced when the mass was highly heated, as, for instance, in its passage near the sun. He found that a piece of the Toluca meteorite, although very tough when cold, would crumble under the hammer when heated to a white heat. He states that it also seems necessary to assume a contact with some other body, as well as a heating, in order to account for the faults. In opposition to this view by Howell the faulting is believed by Brezina, according to a label in the Vienna Museum, to have been the result of the impact of the mass on the earth.

Bent plates.—These are somewhat allied to faults, there having been differential motion in the mass, but not a sufficient amount to produce fracture. Naturally, they are to be noted only in the iron meteorites. Carlton, Glorieta Mountain, Jamestown, Ranchito, and Toluca are some of the meteorites in which they have been observed. The bent plates appear upon an etched surface as curved Widmanstätten figures. They never characterize an entire mass, so far as I am aware, but only portions, and occasionally but a small portion of a single mass. The amount of curvature is not great, rarely if ever exceeding 10^{mm} in 50. A single plate never has more than one direction of curvature, though it is often straight for some distance at one end and curved at the other. With reference to each other, however, the directions of curvature of individual plates may be quite different. Like faults, the bending is referred by Brezina to the result of the impact of the meteorite upon the earth.

Veins (*Adern*, *Filons*, *Veines*).—These occur in many stony meteorites, in fact in a sufficient number to characterize seven of the thirty-seven groups into which Brezina divides stony meteorites. The veins may vary in width from a mere line to 19 millimeters (Mocs). An even greater dimension is indicated by the size of single stones from the Pultusk and Mocs showers, which seem to be of a substance like that of the veins. The veins penetrate the stones now in a nearly straight direction and now in a more or less tortuous one. Sometimes they are single, then again branched, and again ramify to such an extent as to form a network. They are rarely uniform in width for any appreciable distance. On the contrary, they widen and narrow very irregularly, often forking so as to enclose portions of the mass and then meeting again. The Bluff meteorite shows two systems of veins crossing one another at angles of about 45°. The narrower of these is uniform in width and was observed over a plane 4 × 15 inches in extent. The wider varies much in width and is less extensive.

In color, veins are dark, usually black. The substance filling them is black, opaque, brittle, and of a semi-glassy character. In polarized light it appears amorphous and isotropic. It often includes splinters of the adjoining stone and little spheres of nickel-iron and troilite. Along the walls are often seen delicate metallic foliae, lying parallel to the direction of the veins. These appear in cross section like delicate threads. From the nickel-iron grains threads often run out in a direction across that of the vein, and these may pass into empty clefts. In many portions of the stone of Chantonnay narrow, irregular, open fissures occur. Some of these have begun to be filled by matter that has flowed in from the surface, but it has penetrated only to a depth of a few millimeters. The vein substance usually has fairly well-defined walls, but on the other hand may gradually pass into the body of the meteorite. In the stone of Goalpara, which is coarsely porous, a black, vein-like substance forms the walls of the pores, makes up the groundmass, and

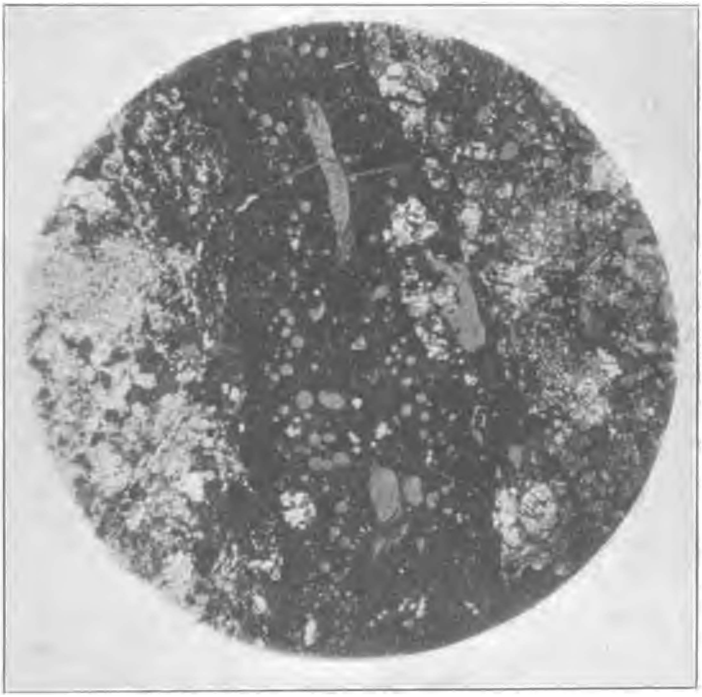


FIG. 11.—Cross section of a vein of one of the Mocs meteorites. The vein mass appears as a broad black band through the center. It is in part intermixed with the adjoining groundmass and in part has well defined walls. The gray spots are spheres and lumps of nickel-iron illuminated by reflected light. The branching of some of these into clefts, one of which is still open, is of interest. × 20. After Tschermak.[1]

---

[1] Op. cit. Tafel XXII, Fig. 2.

penetrates into the minutest fissures. Again, the groundmass of the stone of Richmond is a black, half glassy substance which occupies the spaces between the chondri and spreads itself into their interstices. Thus the veins may occur as mere apophyses of a black groundmass. In fact, apparently the same substance forms veins in the meteorites of Mocs, a cement in the stone of Orvinio, and the entire groundmass of such carbonaceous meteorites as Cold Bokkeveld. That the substance is exactly the same in all these cases cannot be regarded altogether proved as yet, however. An analysis by Whitfield of the vein substance of the Bluff meteorite showed it to be very similar in composition to the mass of the stone. Tschermak states that the vein substance of the Goalpara stone consists of a network of iron, holding troilite, carbon, and a glassy substance found to be decomposed by acids. The substance of the black veins of the Chantonnay meteorite Meunier regards as consisting of a silicate of iron. An interesting experiment performed by him in this connection was that of heating meteorites of the group to which he gives the name of Aumalite, to redness without access of air. The meteorite then became black, of lighter specific gravity, and increased in hardness and toughness. In other words, it became a substance which he regards as exactly similar to that of the veins of Chantonnay. He regards the presence of this substance in the stone of Chantonnay, therefore, as proof that the meteorite had undergone heating or metamorphism before its entrance into the earth's atmosphere.

So far as the general appearance of the black veins is concerned, it may be said with Tschermak that they give the impression that the substance of the meteorite at some time underwent fissuring and that a fused liquid was absorbed into these fissures. The phenomenon must have differed somewhat from that of the injection of fused lava into the interstices of terrestrial rocks, since the substance of the vein mass agrees so closely in composition with that of the substance of the meteorite.

Vein-like filaments.—In passing from the iron to the stony meteorites every gradation may be traced from metallic masses in which the silicates appear as porphyritic ingredients, through those appearing to be made up of interwoven constituents, to those in which the metallic constituents appear as isolated grains. In several of the latter class of meteorites (Farmington, Crab Orchard Mountains, Bluff) long, branching, metal filaments are seen to be associated with the isolated grains.

In the view of the present writer, these are filamentous phases of the structure of the metallic portions of the meteorite. Other meteorites, of which those of Honolulu, Mocs, and Pultusk may serve as illustrations, have what appear to be metallic veins when seen in cross sections. When cleft along the vein, however, these prove to be slickensided surfaces along which the metallic grains of the meteorite have been drawn or flattened out by the movement. These vein-like structures are clearly of different character from those just described. They sometimes give a well-marked appearance of a vein outlined on the crusted surface of a meteorite. This is owing to the fact that resisting fusion more than the stony matter they stand out in relief.

Cleavage and joints.— Most of the cubic irons are characterized by a complete cubic cleavage. This cleavage doubtless indicates that the masses are crystal individuals. Huntington has described cleavage planes as passing through some of the octahedral irons independent of the octahedral structure. It is probable that these, as well as cleavage along the octahedral planes often noted, are separation planes resulting from weathering.

Few stone meteorites are of sufficent size to exhibit a jointed structure if it existed. Meunier has called attention to an elongated depression in one of the L'Aigle stones which he regards as marking the position of a former joint plane. The Long Island meteorite, the largest stone meteorite known, is cut by three large division planes which perhaps represent joint planes. Two of them are at right angles to one another, while the third, somewhat broken, is nearly at right angles to the other two. The great irregularity of form of most meteorites, however, would seem to indicate that division planes were lacking in the masses from which they have separated.

SYNTHETIC EXPERIMENTS IN THE REPRODUCTION OF STRUCTURAL DETAILS

Fouqué and Levy have succeeded in reproducing, so far as the component minerals were concerned, mineral aggregates corresponding to several types of meteorites. Among meteorites not containing feldspar, aggregates were produced corresponding to the meteorite of Rittersgrün, which is made up of chrysolite, enstatite, a magnesian pyroxene, and iron. Among meteorites containing feldspar, aggregates were produced corresponding to those of the class known as Eukrites, which are made up of anorthite, enstatite, and pyroxene, and of the class made up of anorthite, enstatite, and chrysolite. These were all produced by cooling from fusion, different mixtures of silica, alumina, magnesia, carbonate of lime and iron oxide. The chief difference noted by these authors between these products and meteorites of corresponding chemical composition is one of structure. The artificial products were of a marked granitoid texture, while most meteorites have as strongly brecciated or tuffaceous character. It is also true that the iron in the artificial products was in the form of oxide. This could, however, easily be reduced to the metallic state by exposing the mass to the action of reducing gas at a red heat for two hours. Previous to the experiments of Fouqué and Levy stone meteorites of several types had been fused by Daubrée and the resulting cooled products examined. The products resembled the original masses in some respects, but in many respects differed. Thus chrysolite and enstatite separated in a sort of liquation, the chrysolite forming a thin layer above, while the enstatite crystallized below in the form of long needles. Moreover the iron grains took spherical forms rather than the irregular ones which characterize meteorites. Daubrée therefore concluded that the mode of formation of meteorites differed from purely igneous fusion. The needles of enstatite artificially obtained seemed analogous in his opinion to the needles formed on the surface of freezing liquids, while the grains seen in meteorites seem more like the forms of frost or snow formed by the immediate passage of water vapor to the solid state. This conclusion led to a number of experiments by Meunier with vapors of silica, magnesia, etc., for the purpose of forming in this manner if possible mineral aggregates resembling the meteorites The results so far obtained have been chiefly negative, though the experiments are still being conducted. A prominent feature lacking from the results of the experiments with vapors is the glass so abundant in meteorites. This is obtained in quantity however in the products cooled from fusion.

Many efforts have been made to reproduce Widmanstätten figures but they cannot be said to have met with much success. As it is held that the Widmanstätten figures indicate slow cooling from fusion, Sorby fused together iron, nickel, and other constituents of an iron meteorite, and allowed the mass to cool very slowly. On examining an etched surface with a lens, minute lines were seen which recalled the Widmanstätten figures but the appearance as a whole, he states, was very different. The mass was then kept for a long time at a temperature just below that of fusion but the resulting product was less like meteoric iron than that previously obtained. Daubrée fused a portion of the Caille meteorite in a crucible of clay, then allowed the mass to cool slowly. The resultant mass showed a crystalline structure but all trace of the former Widmanstätten figures was lost. On fusing a mixture of iron, nickel, troilite, and silica, he obtained a product showing dendritic figures. On fusing a mass of iron, nickel, and iron phosphate together, a mass having a reticulated structure with angles showing dodecahedral crystallization was obtained, The structure of this mass approached more nearly the Widmanstätten figures than any obtained in any other way, and it is sometimes stated that true Widmanstätten figures were produced. As Cohen remarks, however, the statement needs to be supported by figures and specimens. The same may be said of Meunier's statement that he found Widmanstätten figures on a mass obtained by reducing iron and nickel chlorides from their vapors. J. Lawrence Smith states that he obtained Widmanstätten figures on a button of iron which cupelled from a mixture of iron silicate and chalk heated to fusion for from 15 to 20 minutes in oxygen in excess. If the excess of oxygen was essential to the success of this experiment, it was a condition certainly wanting in the formation of the iron meteorites.

It is true of chondri as of Widmanstätten figures that they have not yet been successfully reproduced by synthetic methods. Especially has it been found impossible to reproduce the structure exhibited by many enstatite chondri, of fibers radiating from a point eccentrically placed with reference to the center. Meunier has obtained from vapors of silicon chloride and magnesium acicular crystals of pyroxene which he recently showed the writer, which radiate in a fashion recalling the above-mentioned chondri. They cannot, however, be said to be in any sense reproductions of the chondri, and they are moreover a monoclinic pyroxene. Perhaps the nearest approach in form to these structures has been obtained recently by Brauns in crystals obtained by cooling sulphur. The forms were produced either by suddenly cooling a strongly heated preparation of sulphur or by slowly cooling and suddenly shaking it. Such results suggest that the peculiar structures of chondri indicate special conditions of cooling or percussion to which the mass has been subjected. If these conditions could be reproduced, chondri could, perhaps, be formed synthetically. It may be suggested that immediate contact with the intense cold of space, a condition which has not yet been experimentally fulfilled, is perhaps the force which has given chondri their peculiar form.

NOTE.—For further study and for lists of references the following works may be consulted: Meteoritenkunde, Heft I, E. COHEN, Encyclopedie chimique, Tome II, Meteorites, S. MEUNIER; Die mikroskopische Beschaffenheit der meteoriten, G. TSCHERMAK.

O. C. FARRINGTON.

FIELD COLUMBIAN MUSEUM,
Chicago.

EDITORIAL

A GEOLOGICAL and geographical excursion in the North Atlantic is planned for the summer of 1901. Conditionally on the formation of a sufficiently large party, a steamer of about 1000 tons, specially adapted for ice navigation, and capable of accommodating sixty men, will leave Boston on or about June 26 and return to the same point on or about September 20. The main object of the voyage will be to offer to the members of the excursion party opportunity of studying the volcanic cones and lava fields, the geysers, ice-caves and glaciers of Iceland, the fiords and glaciers of the west coast of Greenland, and the mountains and fiords of northern Labrador. Some attention will be paid to the hydrographic conditions of the waters traversed. Botanists, zoölogists, ornithologists, mineralogists, and those interested in other branches of natural history may pursue independent studies. A hunting party may take part in the expedition; it could be landed for a fortnight or three weeks in Greenland and for about the same period in Labrador.

An inclusive fee of $500 for each member will be charged, $250 to be deposited with the leader of the expedition on or before March 15, the balance to be paid or on before June 1.

The trip will be under the direction of Dr. R. A. Daly, of the Department of Geology and Geography, Harvard University, Cambridge, Mass. Applications for membership should be addressed to him.

REVIEWS.

ŻEILLER'S *Flora of the Carboniferous Basin of Heraclea: An Illustration of Paleozoic Plant Distribution.*

At a meeting of the Biological Society of Washington in November 1897, the writer exhibited a small number of specimens of Carboniferous plants from Asia Minor, and called especial attention to the precise agreement in detail of several of the species with the corresponding types in our American Coal Measures. Particular emphasis was laid on the remarkable geographical distribution of plant species in Middle Carboniferous time, as to which the material in hand constituted new evidence. This striking agreement in exact form between the American and Asiatic species could not fail to arouse in paleobotanists the keenest interest in the publication of the results of the study of the southeastern flora by Professor Zeiller, to whose courtesy the writer was indebted for the above mentioned specimens.

Professor Zeiller's study of the Carboniferous flora of Heraclea[1] (Eregli) is an admirable example of stratigraphic paleobotany. To the stratigrapher who is unacquainted with the progress made of late years in the differentiation and recognition of the various Carboniferous floras of the Old World, and of their utility as means of correlation, it is an instructive illustration. To paleontologists this close, critical work is especially valuable for the light it throws on the areal distribution of identical species and on the identity and regularity in sequence of the floral associations characteristic of the several stages.

The fossil plant material, chiefly collected by M. Ralli, was obtained from several isolated areas in two of which the structure is particularly complicated, the terranes being diversely and frequently faulted, or even shattered. The collections from these areas are found by Zeiller to embrace 122 species which, when grouped by localities, very distinctly indicate three stages of the Carboniferous, which M. Ralli also is able to recognize stratigraphically in portions of the territory, although the complex structure hardly admits of correlation without paleontological aid.

---

[1] Étude sur la flore fossile du bassin houiller d'Héraclée (Asie Mineure). R. Zeiller, Mém. Soc. géol. Fr., Paléontologie, mém. 21, Paris, 1899, 91 pp., 6 pl.

In the following paragraphs the general paleontological features of the three stages will be outlined, together with the correlations proposed by Zeiller. To this will be added comments on certain of the Heraclean plant types with some suggestions as to the relations of the Heraclean Carboniferous floras to those of eastern North America.

A. The lowest of the three paleobotanical stages recognized by Zeiller in the material examined is that of Aladja-Agzi. In the collections from several localities representing this stage in the various areas, he finds:[1]

Sphenopteris dicksonioides,* *S. bermudensiformis*, *S. Larischi*,* *S. divaricata*,* *Rhodea* cf. *Stachei*, *Diplotmema dissectum*, *D. elegans*,* *Adiantites oblongifolius*,* *Pecopteris aspera*, *Archæopteris*, sp., *Cardiopteris polymorpha*, *Sphenophyllum tenerrimum*,* *Asterocalamites scrobiculatus*,* *Calamites ostraviensis*, *C. ramifer*,* *Lepidodendron acuminatum*,* and *Lepidophyllum lanceolatum*.

Two additional species are described as new, viz.: *Sphenopteris bithynica* and *Sphenophyllum Sewardi*.

Of the previously described species, all in the above list, with the exception of the undeterminable *Archæopteris* and the *Lepidophyllum lanceolatum* are also present in the Ostrau-Waldenburg (Upper Culm) stage of Silesia, with which the Aladja-Agzi flora is correlated by Professor Zeiller. The species marked by the asterisk (*) in the above list are also recorded from the Appalachian Pottsville, with whose lower portion the Ostrau-Waldenburg beds are probably, in part, at least, contemporary, as has already been elsewhere[2] indicated. Of the remaining plants *Sphenopteris bermudensiformis* is evidently closely related to a form from the Pottsville referred to *S. asplenioides*; while the specimens figured as *Diplotmema dissectum* appear to find a corresponding form in the latter formation. *Sphenopteris bithynica* seems to be extremely close to *S. subfurcata* Dn. from the supposed "Middle Devonian" [Pottsville] at St. John, N. B., while *Sphenophyllum Sewardi* stands in a similar relation to *S. tenue*[3] from the Welch formation (Middle Pottsville). With reference to the _Lepidophyllum lanceolatum_ listed above, I would add that the specimen figured by Professor Zeiller would seem to agree with the _L. Campbellianum_ described by Lesquereux from the Pottsville. The latter is much more slender, acute and narrowed toward the relatively small sporangiophore than is the quite distinct type, from the higher Coal Measures, identified by Lesquereux as _L. lanceolatum_ L. and H. _Cardiopteris polymorpha_ has not in this country been found in beds so high as the Pottsville, though it is present in beds of Chester age.

---

[1] The nomenclatural orthography in the following list is that used by Professor Zeiller.

[2] Bull. Geol. Soc. Amer., Vol. VI, p. 320, 1895. See also: Twentieth Annual Rept. U. S. Geol. Surv., Pt. II, p. 912.

[3] Twentieth Annual Rept. U. S. Geol. Surv., Pt. II, 1900, p. 900, Pl. CXCI, Figs. 6, 7.

_B._ Above the Pero bed at Kilimli, whose flora belongs to the Aladja-Agzi stage, and separated from that bed by a conformable series of sandstones and conglomerates 90 meters in thickness lies the Sinork coal, with which are found _Mariopteris acuta_, _Asterophyllites grandis_, and _Lepidodendron Veltheimi._ The first two named are characteristic of the Westphalian of Europe, while the third is present in the Culm as well. The more exact place of this florula is in the lowest of the three stages of the Westphalian. All three species are present also in the lower group of the Kanawha formation in West Virginia. The plants accompanying the coals mined at Coslou (Kosloo) as well as those from a number of other localities, many of which are in faulted blocks, belong to the same stage as the Sinork plants, though some of the localities are evidently at a lower horizon in that stage than others.

The entire flora from this stage includes: _Sphenopteris obtusiloba_*, _S. Schillingsi_*†, _S. Baeumleri_, _S. Frenzeli_, _S. schatzlarensis_, _S. Sauveuri_*†, _S. Crepini_*†, _S. Laurenti_*†, _S. Hoeninghausi_*, _S. tenella_*†, _S. Aschenborni_, _S. Schwerini_, _S. Karwinensis_, _S. Vüllersi_, _S. bella_, _S. Sternbergi_, _Rhacopteris subpetiolata_, _Palmatopteris furcata_*, _P._ cf. _elegantiformis_*, _Mariopteris muricata_*†, _M. acuta_*†, _Pecopteris plumosa_*†, _P. aspera_, _P. pennæformis_*, _Alethopteris Davreuxi_, _A. decurrens_*†, _A. Lonchitica_*†, _Lonchopteris Eschweileriana_, _Nevropteris gigantea_*†, _N. Schlehani_*†, _N. heterophylla_*, _Sphenophyllum cuneifolium_ (old form)*†, _Calamites Suckowi_*, _C. undulatus_*(?), _C. Cisti_*, _C. ramosus_*, _C. Schützei_, _C. distachyus_, _Asterophyllites grandis_*†, _A. equisetiformis_*, _Annularia galioides_*, _A. Radiata_*†, _Radicites columnaris_*, _Lepidodendron lycopodioides_, _L. aculeatum_*, _L. dichotomum_*, _L. obovatum_*†, _Lepidophloios laricinus_*, _Lepidostrobus Geinitzi_*, _Lepidophyllum lanceolatum_*, _Sigillaria elegans_*, _S. elongata_*, _S. Schlotheimi_*, _S. scutellata_*, _S. Davreuxi_*, _S. Boblayi_, _S. mamillaris_*, _S. germanica_, _Stigmaria ficoides_*, _Cordaites principalis_*, and _Dorycordaites palmæformis._

The new types described from this stage are *Sphenopteris Ralli*, *S. heracleensis*, *Potoniea adiantiformis*, *Calamophyllites vaginatus*, *Phyllotheca Ralli*, and *Sigillaria euxina*.

All but six of the species listed above are present in one or more of the European basins. The flora of the lower horizon is referred to the lowest of the three stages of the Westphalian, while that of the slightly younger horizon is regarded as overlapping on the lower or transition portion of the middle stage.

It is impracticable to discuss in this place the relations of the large and interesting flora from this stage to the floras of the United States. I have, however, marked with the asterisk (*) those species that are recorded from the Carboniferous of North America.

The percentage of identical species is undoubtedly fully as large as that marked in the list. Of the American representatives among the fern species the greater portion are present either in the Kanawha formation of southern West Virginia and Kentucky, or the upper portion of the Pottsville formation. In fact the flora of the lower horizon in the Coslou group is clearly comparable to the topmost Pottsville and earlier Kanawha plant associations. The flora of the upper horizon of the Coslou group has little in addition besides the Sigillarias that is common to the Allegheny series, and it, too, is distinctly older than that series, though it appears hardly so typical as the other flora of the Lower Kanawha group. The surprisingly close relations of the flora of the Coslou stage to the uppermost Pottsville, and particularly to the Lower Kanawha flora will be better understood when the detailed studies of the latter floras are published. Suffice it for the present to say that the species marked by the (†) in the above list are, so far as I have observed, peculiar to and characteristic of this combined portion of the Appalachian Upper Carboniferous section.

A few among the more important species closely related to American types deserve special mention: *Sphenopteris Vüllersi* is very close to a variety of *S. furcata* from the Southern Anthracite field; *S. Sternbergi* to *Aloiopteris* (*Sphenopteris*) *georgiana* of the Pottsville; and *Alethopteris Davreuxi* differs but little from the latest phase of *A. grandifolia*. My remarks on the *Lepidophyllum lanceolatum* in the lower stage probably apply equally to the Coslou specimens.

As *Potoniea* Zeiller describes a type of fructification whose fleshy adiantiform divisions are studded or fringed with fusiform bodies suggesting the sporangia of *Crossotheca* (*Sorocladus* of Lesquereux). It is regarded by him as belonging more probably to a fern, though it is possibly gymnospermous. *Phyllotheca Ralli* is an extremely interesting type whose fructification appears to be very close to that of the living *Equisetum*, while the leaf sheath, suggestive of *Annularia radiata*, is very similar to that of an undescribed species from the lower Kanawha group of West Virginia. The genus *Phyllotheca*, which is present in the Indo-Australian *Glossopteris* flora (Permo-Carboniferous), and which for a long time was supposed not to have appeared in Europe until the Jurassic, has later been described from the Permian and is now known in the Coal Measures of both Europe and America.

C. The upper or Caradons stage in the Heraclean basins is represented by many localities whose largely common floras evidently lie in or near the same stage. Its flora includes: *Sphenopteris* (*Crossotheca*) *Crepini**, *S. Bronni**, *Palmatopteris alata**, *Pecopteris Miltoni**, *P. oreopteridia**, *P. unita**, *P. Roehli*, *P. plumosa**, *P. Pluckeneti**, *P. Newberryi**, *Alethopteris Serli**, *A. Grandini**, *Odontopteris britannica**, *O. Reichiana**, *Nevropteris Scheuchzeri**, *N. heterophylla**, *N. rarinervis**, *N. tenuifolia**, *Linopteris obliqua**, *L. Münsteri*, *Caulopteris patria*, *Ptychopteris macrodiscus*, *Sphenophyllum cuneifolium**, *S. emarginatum**, *S. oblongifolium*, *S. majus**, *Annularia stellata**, *A. sphenophylloides**, *Lepidodendron Jaraczewski*, *Sigillaria tessellata**, *Cordaites borassifolius**, *Cordaites principalis**, *Cordaicarpus congruens**, and *Samaropsis fluitans**.

Five species, *Sphenopteris Limai*, *Pecopteris Armasi*, *Alethopteris pontica*, *Linopteris elongata*, and *Plinthiotheca anatolica*, have not been found elsewhere.

In the above list the asterisk (*) denotes an American distribution for the species, most of which are familiar to those geologists who have observed the plants of the Coal Measures in the northern bituminous basins. Among them *Pecopteris Miltoni*, *P. unita*, *P. Pluckeneti*, *P. Newberryi*, *Alethopteris Serlii*, *A. Grandini*, *Odontopteris britannica*, *O. Reichiana*, *Nevropteris Scheuchzeri*, *N. rarinervis*, *Linopteris obliqua*, *Sphenophyllum emarginatum*, *S. oblongifolium*, *S. majus*, *Annularia stellata*, *and A. sphenophylloides* are characteristic of the Allegheny series and higher Coal Measures.

The flora of the Caradons stage contains a mingling of uppermost Westphalian species with Stephanian types. This flora is correlated by Zeiller with that of the stage of the Radstock Series in England, the Geislaütern beds in the Saar region, the "middle series" in the

Zwickau basin of Saxony, the Schwadowitz beds in lower Silesia, and with the Mazon Creek, Illinois, flora of the United States.

The flora of Mazon Creek seems to find its place in the Kittanning group of the Pennsylvania basins, and probably near the horizon of the Middle Kittanning coal. The presence of certain species, particularly of *Odontopteris*, of abundant *Linopteris obliqua*, of *Pecopteris Miltoni*, of *Alethopteris Grandini*, and of *Sphenophyllum oblongifolium* in the Heraclean flora leads me to conclude that the Caradons material was derived from beds slightly later than the Mazon Creek horizon, or perhaps as high as the Freeport group, which is next above the Kittanning group, though also within the Allegheny series. *Sphenopteris Crepini*, which is probably present in the upper Kanawha group, is very closely related to *Sphenopteris sagittata* from Mazon Creek and *S. ophioglossoides* from the Des Moines series of Missouri. *Sphenopteris Bronni*, *Nevropteris tenuifolia*, *Sphenophyllum cuneifolium* and *Cardiocarpus congruens* are perhaps the only species whose presence in the Caradons flora argues, on the one hand, for a horizon lower than that of Mazon Creek. The far more important and abundant evidence of the fern elements is, on the other hand, for a rather later date.

The most interesting of the plants newly described from the Caradons beds are *Pecopteris Armasi* and *Plinthiotheca anatolica*. The former appears to form a connecting link between *Pecopteris* and *Callipteridium*. *Plinthiotheca* is represented by thick, fleshy peltate or cyclopteroid leaves, radiately densely vascular and covered by small capsules arranged in fours in contiguous squares. These capsules are regarded by Professor Zeiller as sporiferous, rather than polleniferous; and the type is therefore tentatively ranged by him with the ferns instead of with the Doleropteroid gymnosperms. The examination of Zeiller's figures and a careful comparison of the types of *Dolerophyllum pennsylvanicum* in the Lacoe collection convinces me that the Heraclean type is generically identical with that described from Pennsylvania by the late Sir William Dawson.[1]

The generally close agreement mutually between Professor Zeiller's correlations of the Heraclean floras in Europe or this country with my own correlations of the Middle Pottsville, the Lower Kanawha, and the Allegheny series well illustrates the marked paleobotanical differentiation of the stages, and the regularity of the sequence, as well as the extraordinary geographical distribution of the several Middle

---

[1] Can. Rec. Sci., Vol. VI, p. 8, 1890.

Carboniferous floras. Of the 122 species contained in the collections from the three Heraclean stages not more than eleven are unknown in Europe or America.

David White.

Géologie et minéralogie appliquées. Les minéraux utiles et leur gisements. Par Henri Charpentier. Pp. 643 + xi; illustrated, 12mo. Paris, 1900.

This volume forms a part of the *Bibliothèque du Conducteur de Travaux Publics* of France, and is published under the auspices of the ministers of public works, of agriculture, of public instruction, of commerce and industry, etc. Its title-page is followed by the *Comité de patronage*, a list of thirty-nine prominent government officials, and by the editing committee with twenty-seven additional and equally distinguished names; then comes a preface written by the chief engineer of mines.

A work upon economic geology, introduced with these impressive formalities and distinguished approvals, one naturally expects to find of unusual merit and importance. The general plan of the work is very like that followed by Fuchs and De Launay in their large and excellent *Traité des Gîtes minéraux et métallifères*, published in 1893; but this work by Charpentier is evidently intended to be more elementary and for a less instructed class of readers.

The first seventy-four pages are devoted to general geology, mineralogy and paleontology. In the second part the economic-geologic subjects are taken up in the following order:

(1) Building materials, (2) Metallurgical minerals, (3) Carbon and its compounds, (4) Fertilizers, (5) Miscellaneous minerals, (6) Rare metals, (7) Precious stones.

These topics are properly subdivided and treated separately, and at the end of each discussion is a list of bibliographic references that varies in length from one to thirty or more titles chronologically arranged. The economic geology of France naturally occupies the first place, but those of other countries are also treated at such length as to lead one to suppose that the book was expected to be useful outside of France.

The bibliography given after each topic will appeal to busy readers as especially useful. In the preface it is stated that this *bibliographie fort complète* will do away with tiresome searching for literature by those who want to go deeper into the subjects treated. We venture to hope that the busy reader will be more fortunate in the use of these references than we have been. To one somewhat acquainted with the general literature of economic geology these lists are more remarkable for what they do not than for what they do contain. What must geologists and mining engineers in any part of the world think of bibliographies with such omissions as the following? Under Building Stones no reference is made to Merrill; under Copper no mention of Whitney, Irving, or Wadsworth; under Zinc no mention of Winslow; under Phosphates and Manganese no mention of Penrose; under Quicksilver no reference to Becker; under Petroleum and Natural Gas no mention of Carll or Orton; under Silver no reference to Emmons; and under Diamonds no mention of the writings of Derby.

The references that are given are often quite irrelevant, and sometimes wrong. For example under the list upon "combustible minerals," p. 405, is this: "1871. Hartt. *La faune carboniferienne du Missouri* (Neues Jahrb., p. 63)." The place cited contains a note by Louis Agassiz upon the Carboniferous fauna found by Hartt in South America. There is not a word about Missouri, and as a matter of fact there is no coal in the South American Carboniferous area mentioned by Hartt. On p. 406 is this: "1878. Derby. *Le carboniferien au Missouri* (Neues Jahrb., p. 663)." There is no such article at the page cited, and I much doubt Professor Derby's having written such an article at all. On p. 538 the bibliography of kaolin gives a title by Fontannes. Upon looking up the article cited it is found to contain nothing about kaolin. In addition to these defects the typographical errors in the references render many of them worthless.

The book seems to be intended for a sort of *vade mecum* on economic geology, and as such it will be found helpful. It is of convenient size and neatly bound in flexible leather.

J. C. BRANNER.

Handbuch der Seenkunde. Allgemeine Limnologie. Von DR. F. A. FOREL. Stuttgart: Verlag von J. Engelhorn.

This volume is one of the series of useful geographic handbooks published under the general editorship of Professor Dr. Friedrich Ratzel. It brings together in concise, comprehensive, and readable form the general principles of limnology.

The first part of the volume is devoted to a discussion of lake basins, the discussion covering the origin of lake basins and of lakes, the obliteration of the basins, and the deposits made in them.

The second and larger part of the volume deals with the waters of lakes. Here are included (1) Hydrology—supply and waste; (2) Hydraulics, including the pressure of the water, the levels of lakes, their changes, permanent and temporary, rhythmic and non-rhythmic, the waves, seiches, currents, etc.; (3) Chemistry, including the comparative study of the waters flowing into the lakes, that in the lakes, and that flowing from them. Comparisons are also made with sea water; (4) The temperature of lakes, including a discussion of surface temperatures, their areal and periodic variations, comparisons of the temperature of the surface water with that of the overlying air, and the temperature of the sub-surface waters; a section is also given to the freezing of the lake water; (5) Optics, including the penetration of light, the color of the water, reflection, refraction, etc., under various conditions; (6) The biology of lakes. Besides the more obvious topics considered in this chapter, a section is given to the origin of lacustrine societies, and another to the physiology of lacustrine organisms.

In an appendix is given an outline for the prosecution of lacustrine studies, and also a bibliography.

The volume is the best brief compendium on the subject with which it deals. R. D. S.

A Preliminary Report on the Artesian Basins of Wyoming. Bulletin 45 of the Wyoming Experiment Station. By WILBUR C. KNIGHT.

While this report is primarily a consideration of the artesian basins of the state, its first part is devoted to a summary of existing knowledge concerning the geology of the state. The following systems of rocks are represented: Archean, Algonkian, Cambrian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Eocene, Oligocene, Miocene, and Pleistocene.

The Archean is found at various points in the mountain ranges. The Algonkian has a similar distribution, with a total maximum thickness, including some igneous rock, of 20,000 feet. Following the deposition of the Algonkian rock were great disturbances and elevations, followed by a prolonged period of erosion. The late Cambrian and late Ordovician periods are represented by relatively thin formations, chiefly of limestone. The Ordovician is found only in the northern part of the state, and the Devonian, so far as now known, only in the northwestern. As elsewhere in this part of the United States, the Devonian seems to rest conformably on the Ordovician. The Carboniferous is more fully represented than the preceding systems. The Lower Carboniferous is found only in the northern half of the state, while the Upper is more widespread. Limestone is the dominant rock. The Permian occurs in the Laramie, Big Horn, and Wind River mountains. It has but slight thickness, 200 feet or so, but has the fauna characteristic of the period.

The Mesozoic systems are much more fully represented, being in the aggregate 20,000 to 30,000 feet thick. They are in general conformable on the Paleozoic.

The Triassic system is represented by the Red Beds, which are gypsiferous and without fossils. The Jurassic system is represented by a marine division, the Shirley formation, overlaid by a fresh-water division, the Como formation. Both formations are referred to the later third of the Jurassic period. No special reasons are given for assigning the Como to the Jurassic, rather than to the Lower Cretaceous. This formation is said to have covered most, if not all of the state, and its character is such as to indicate marshy and lacustrine conditions.

The Cretaceous formations are the most extensive in the state. They cover about 50,000 square miles, and the thickness is 20,000 to 25,000 feet. The following formations are present: The Dakota, Bear River, Fort Benton, Niobrara (which contains some chalk), the Fort Pierre and Fox Hills formations, which together are, at the maximum, something more than two miles thick, and the Laramie, which has a thickness of about one mile. The Montana division (Fort Pierre and Fox Hills) contains some oil and coal, and the Laramie much coal. The Fort Union beds are also placed with the Cretaceous, with a question.

The areas of the Tertiary rocks are characterized by the Bad Land topography. The Eocene is represented by the Bridger, Green River, and Wasatch beds; the Oligocene by the White River beds; the Miocene by the Loup Fork. The Eocene beds have an aggregate thickness of 3500 feet, the White River of 1500, and the Loup Fork of 500. Pliocene beds are not known.

During the Pleistocene there were very considerable glaciers in the Wind River, Absaroka, Shoshone, Big Horn, and Medicine Bow mountains, as well as in the Yellowstone Park. Glaciers also reached the state line from the Uinta Mountains. No subdivisions of the glacial period have been made out.

The report is accompanied by an uncolored geological map, which is, we believe, the first geological map of the state which has been published. R..D. S

Die vierte Eiszeit im Bereiche der Alpen, von ALBRECHT PENCK. Vorträge des Vereines zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. XXXIX. Jahrgang. Heft 3, 1899.

In this little pamphlet, as the title implies, Dr. Penck recognizes four distinct epochs of glaciation (instead of three as heretofore) in the Alps. The additional epoch which is here added belongs to the earlier rather than to the later stage of the glacial period. The differentiation of these several epochs is based primarily on the topographic distribution of the deposits made by the waters which flowed from the ice, the deposits of the several epochs being so disposed as to show very considerable periods of erosion between the periods of fluvioglacial deposition.

This paper is of interest in that it helps to bring the phenomena of this somewhat isolated area of glaciation into still closer correspondence with the phenomena of the greater areas of glaciation in northwestern Europe and North America.

R. D. S.

RECENT PUBLICATIONS

—ALLENSPACH, G. Dünnschliffe von gefälteltem Röthidolomit-Quartenschiefer am Piz Urlaun. Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich. Druck von Zürcher & Furrer in Zürich.

—American Association for the Advancement of Science, Proceedings of. Vol. XLIX, New York meeting, June 1900.

—American Museum of Natural History, Bulletin of the. Vol. XIII, 1900. New York, December 1900.

—Astronomical Observatory of Harvard College, Annals of. Edward C. Pickering, Director. Vol. XLIII. Part 1. Observations and Investigations made at the Blue Hill Meteorological Observatory, Massachusetts, U. S. A., under the direction of A. Lawrence Rotch. The Eclipse Cyclone and the Diurnal Cyclones, by H. Helm Clayton. Published by the Observatory, Cambridge, 1901.

—Australasian Institute of Mining Engineers, Proceedings of. First ordinary meeting, 1900, Melbourne, Victoria.

—BAKER, FRANK COLLINS. A Revision of the Limnaeas of Northern Illinois. Transactions of the Academy of St. Louis, Vol. XI, No. I. Issued January 16, 1901.

—CASE, E. C. The Vertebrates from the Permian Bone Bed of Vermilion County, Illinois. [Contributions from Walker Museum, Vol. I, No. 1.] The University of Chicago Press, January 1901.

—CLAYTON, H. HELM. The Eclipse Cyclone and the Diurnal Cyclones. Results of Meteorological Observations in the Solar Eclipse of May 28, 1900. Proceedings of the American Academy of Arts and Sciences, Vol. XXXVI, No. 16, January 1901.

Studies of Cyclonic and Anti-Cyclonic Phenomena with Kites. Bulletin No. 1, 1900, of the Blue Hill Meteorological Observatory.

—Connecticut Academy of Arts and Sciences, Transactions of the. Vol. X, Part 2. New Haven. Published by the Academy, 1900.

—CROSBY, W. O. Geological History of the Nashua Valley during the Tertiary and Quaternary periods. Reprinted from Technology Quarterly, Vol. XII, No. 4, December 1899.

Notes on the Geology of the Sites of the Proposed Dams in the Valleys of the Housatonic and Ten Mile Rivers. Reprinted from Technology Quarterly, Vol. XIII, No. 2, June 1900.

On the Origin of Phenocrysts, and the Development of the Porphyritic Texture in Igneous Rocks. [From the American Geologist, Vol. XXV, May 1900.]

Outline of the Geology of Long Island in its relations to the Public Water Supply. Reprinted from Technology Quarterly, Vol. XIII, No. 2, June 1900.

Report on Borings for the East Boston Tunnel.

—GORDON, C. H. Geological Report on Sanilac County, Michigan. With 5 plates and 2 figures, including one colored map. Geological Survey of Michigan, Vol. VII, Part 3. Lansing, 1900.

—HAYCOCK, E. Records of Post-Triassac Changes in Kings County, Nova Scotia. Reprinted from the Transactions of the Nova Scotian Institute of Science, Vol, X, Session 1899–1900.

—HEIM, ALBERT. Gneissfältenung in alpinem Centralmassiv. ein Beitrag zur Kenntnis der Stauungsmetamorphose. Vierteljahrsschrift in Zürich. Druck von Zürcher & Furrer in Zürich.

—HITCHCOCK, C. H. Volcanic Phenomena on Hawaii. Bulletin of the Geological Society of America, Vol. XII, pp. 45–56, Pls. 2–5. Rochester, December 1900.

The Story of Niagara. Reprinted from the American Antiquarian, January 1901.

—LEE, WILLIS T. Origin of the Débris-Covered Mesas of Boulder, Colorado. Reprinted from the JOURNAL OF GEOLOGY, Vol. VIII, No. 6, September-October 1900.

—LIEBHEIM, E. Beiträge zur Kenntniss des lothringischen Kohlengebirges. Abhandlungen zur geologischen Specialkarte von Elsass-Lothringen. Neue Folge, Heft IV. Atlas. Strassburg in Elsass. Strassburger Druckerei und Verlags-Anstalt, vormals R. Schultz & C^{ie}, 1900.

—LYMAN, BENJAMIN SMITH. Importance of Topography in Geological Surveys. A reprint from the Mining and Metallurgical Journal of December 1, 1900. Vol. XXIII, No. 5, p. 67.

Notes on Mine Surveying Instruments, with special reference to Mr. Dunbar D. Scott's paper on their evolution, and its discussion. [Transactions of the American Institute of Mining Engineers — Canadian Meeting, Angust 1900.]

Movements of Ground Water. Reprinted from the Journal of the Franklin Institute, October 1900.

—Maryland Geological Survey, Alleghany County. Baltimore, the Johns Hopkins Press, 1900.

—NORDENSKJÖLD, OTTO. Om Pampasformationen. Meddelanden från Upsala Universitets Mineralogisk-Geologiska Institution. 25. P. A. Norstedt & Söner, Stockholm.

THE
JOURNAL OF GEOLOGY

APRIL–MAY, 1901

THE CLASSIFICATION OF THE WAVERLY SERIES OF CENTRAL OHIO[1]

INTRODUCTION

PERHAPS it may seem strange that a consideration of the classification of the Waverly series[2] is proposed after the thorough investigations of the Ohio Geological Survey directed by Doctors Newberry and Orton. Their investigations gave the world the main facts concerning the economic and general geology of the state and the names of Newberry and Orton will be associated for all time with the geology of Ohio as those of Mather, Emmons, Vanuxem, and Hall are with that of New York, and Henry D. Rogers and Lesley with that of Pennsylvania. It is true of geology, however, as of other sciences that the scope is constantly widening so that a restatement of facts or, perhaps, another investigation of the whole subject, aided by later discoveries, may be required. At present this is especially true with reference to the stratigraphical geology of America. During the lifetime of Dr. Newberry the nomenclature of geological formations was not closely scrutinized and there were very few clearly defined rules governing the naming of the various geological divisions. In general, the names referred to some locality in which the rocks were more or less favorably exposed. But this was not always the case, for not infrequently mineralogical or paleontological terms were used for the names of the divisions. Much the same system prevailed during the period of the more active investigations of Dr. Orton and it is only during the last few years that the movement has arisen to place the nomenclature of stratigraphical geology on a basis similar to that of the biological sciences. Two of the most potent influences in this movement are the International Congress of Geologists and the United States Geological Survey. The most important principles of nomenclature governing the United States Survey are: first, a formation is a lithological unit representing the physical conditions of deposition, and should be called by the same name so far as it can be traced and identified by means of its lithologic characters aided by its stratigraphic associations and its contained fossils. The formation shall receive a distinctive designation, the preferred form being binomial of which the first member is geographic and the other lithologic. When the formation, however, consists of beds differing in lithologic character, so that no single lithologic term is applicable, the word "formation" shall be substituted for the lithologic term. The second principle is the rule of priority.[1] These two principles of nomenclature have been very imperfectly observed in most of our stratigraphical geology and as recently as December 1899, Dr. J. M. Clarke, state paleontologist of New York, and Mr. Charles Schuchert published a revised classification of the formations of New York in which a number of time-honored names were replaced by new terms.[2]

---

[1] Published by permission of Professor Edward Orton, Jr., state geologist of Ohio. Presented to the tenth meeting of the Ohio State Academy of Science, Columbus, December 27, 1900.

[2] Series is used in the sense proposed by the International Congress of Geologists. See Work Inter. Cong. Geologists, 1886, p. 50; GILBERT, in Proc. A. A. A. S., Vol. XXXVI, 1888, p. 186; and Congrès Géologique International (8e Session), Procès-verbaux des Séances, 1901, p. 34.

REVIEW OF FORMER CLASSIFICATIONS

In 1838 Professor C. Briggs, Jr., the fourth assistant geologist of the first geological survey of Ohio, proposed the name

---

[1] Tenth Ann. Rept. U. S. Geol. Surv., 1890, pp. 64, 65.

[2] Science, N. S., Vol. X, 1899, pp. 874–878.

"Waverly sandstone series" for the rocks occurring between the "argillaceous slaty rock, or shale stratum," now known as the Ohio shale, and the "conglomerate" which lies at the base of the Coal-measures. Waverly is the name of the capital of Pike county in southern Ohio and Professor Briggs stated that "As some of the most beautiful stones that have been obtained were quarried at Waverly, we may, for the present, denominate these rocks the Waverly sandstone series."[1]

In the following report, for some reason, Professor Briggs used the term "fine-grained sandstone" in place of the Waverly in his descriptions of the geology of Hocking, Athens, and Crawford counties.[2]

In the first report of the Newberry survey, Dr. Newberry and Professor Andrews revived the name, "Waverly sandstone."[3] Professor Andrews stated that it consisted of "A group of sandstones and shales, measuring on the Ohio River 640 feet in thickness (from the black slate to the base of the sub-Carboniferous limestone in the Kentucky hills), [which] rests conformably upon the black slate."[4] He further described a stratum of bituminous black shale 16 feet in thickness, 137 feet above the base of the group to which he gave the name "Waverly black slate."[5] It was also stated that between the Coal-measures and Waverly in Hocking county was "a group of comparatively fine-grained, buff-colored sandstone," 133½ feet in thickness which was named the Logan sandstone."[6] Below the Logan sandstone was given 85 feet of rocks which were stated to be composed of fine-grained sandstones alternating with conglomerates and this division in some parts of the report is called the "Waverly conglomerate."[1] Professor Andrews identified these two divisions in the Licking Valley and stated that "at Black Hand, near the east line of Licking county, the conglomerate is probably fifty or sixty feet thick, and over it lies, as we follow the dip to the southeast toward Zanesville, the Logan sandstone group. The Logan sandstone, with its characteristic fossils, is found to extend to a point between Pleasant Valley and Dillon's Falls, on the Baltimore and Ohio Railroad."[2]

---

[1] First Ann. Rept. Geol. Surv. Ohio, p. 80.

[2] Second Ann. Rept. Geol. Surv. Ohio, 1839, pp. 122, 130. See also his section of the strata of Ohio, facing p. 109. The same term was used by Mr. Foster, another assistant; see pp. 76 and 103, and, facing p. 73, his "Geological section along the National road from the Scioto River to the eastern line of Muskingum county."

[3] Geol. Surv. Surv. Ohio, Pt. I, Rept. Progress in 1869, 1870, p. 21; Pt. II, p. 65.

[4] *Ibid.*, Pt. II, p. 65.

[5] *Ibid.*, p. 66.

[6] *Ibid.*, p. 76. The "section on Hocking River" on the "map showing the Lower Coal Measures" at the close of this report gave the thickness of the Logan sandstone group as 144 feet.

Dr. Newberry stated that the Waverly group, as it was then called, "In the northern part of the state . . . . is much less homogeneous [than in the southern part], and is composed of the following elements:

	Feet
Cuyahoga shale (dove-colored shale and fine blue sandstone)	150
Berea grit (drab sandstone)	50
Bedford shale (red and blue clay shale)	60
Cleveland shale (black bituminous shale)[3]	20–60."

This classification was repeated by Dr. Newberry in 1873 in his report on the geology of Cuyahoga county, with a revision of the thickness of the several divisions, as follows:

		Feet
Waverly group	Cuyahoga shale	150–200
	Berea grit	60
	Bedford shale	75
	Cleveland shale[4]	21–60

At a later date the Cleveland black shale was referred by Dr. Orton and some other geologists to the Devonian system. The same classification for the Waverly was given by Dr. Newberry in 1874 under his description of the Carboniferous system.[5] In this volume Professor N. H. Winchell reported numerous outcrops of the Berea grit succeeded by the Cuyahoga shales and sandstones in northern central Ohio in Crawford, Morrow, and Delaware counties.[1] This identification of Professor Winchell's is important because it carried correctly, for the first time, the Berea grit with the overlying Cuyahoga shale from northern Ohio to the central part of the state. Dr. Orton published the descriptions of the geology of Pike and Ross counties in this volume, and gave the following subdivisions of the Waverly series:

---

[1] See p. 135 and explanation of the "section on Hocking River" on the "map showing the Lower Coal Measures."

[2] *Ibid.*, p. 79. Also see *ibid.*, Rept. Progress in 1870 [1871], p. 59.

[3] *Ibid.*, Pt. I, Rept. Progress in 1869, p. 21.

[4] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, p. 184.

[5] *Ibid.*, Vol. II, Pt. I, p. 87.

At the base are from 80 to 100 feet of the *Waverly shales*,[2] a name apparently proposed by him. This was followed by what he termed the *Waverly Quarry System*, with a thickness of 32½ feet, one mile south of Jasper.[3] Immediately above the sandstone is a black shale, from 16 to 27 feet in thickness, which, Dr. Orton stated, had been "designated by the chief geologist the '*Cleveland shale*' and by Professor Andrews the '*Waverly black slate;*'"[4] while the remaining part of the series, including everything "above the Waverly black slate and below the Carboniferous series" was denominated the Upper Waverly, composed of shales and sandstones with a maximum thickness not exceeding 425 feet.[5]

Meek in 1875, in giving the horizon of *Discina* (*Orbiculoidea*) *Newberryi* Hall, stated that certain specimens came "from the Berea shale, a member of the Waverly group of the Lower Carboniferous,"[6] which is, apparently, the first usage of the name in a stratigraphical sense, although it does not clearly appear that Meek intended to separate the shale from the subjacent Berea grit.

In 1878 Dr. Orton's "Report on the geology of Franklin county" was published, and in it occurs a description of the Waverly group as far as represented in the county. The Huron shale, the youngest formation of the Devonian system, was described as closing with "a red or chocolate-colored band, from

---

[1] *Ibid.*, pp. 240, 259, and 280.

[2] *Ibid.*, p. 619. [3] *Ibid.*, p. 621. [4] *Ibid.*, p. 624. [5] *Ibid.*, p. 649.

[6] Rept. Geol. Surv. Ohio, Vol. II, Pt. II, Palæontology, p. 278. See also statements in explanation of Plate XIV.

15 to 20 feet in thickness." Outcrops of these red shales were mentioned as occurring at "Taylor's Station, in Jefferson township, and at several points in Mifflin township, on the eastern bank of Big Walnut Creek. One exposure in particular may be named, which is very conspicuous, viz., the one seen in the slate cliff, opposite Central College."[1]

Dr. Orton's correlation of the divisions of the Waverly was as follows:

		Feet
Waverly group of the sub-Carboniferous period	Cleveland shale - - -	15
	Waverly quarry system -	60
	Waverly shales[2] - - -	10–20

In the report above mentioned Dr. Orton said "the Cleveland shale of Dr. Newberry, the Waverly black shale of Professor Andrews . . . . is known at but a single locality in the county, viz., at Ealy's Mills, in Jefferson township, on the banks of Rocky Fork. From 10 to 15 feet of this formation are here shown within the compass of an acre."[3] Dr. Orton further stated that Professor Winchell was in error in correlating the sandstone at Sunbury, Delaware county, with the Berea grit, his statement being as follows: "The Sunbury stone is erroneously referred in Vol. I [Vol. II] to a higher division of the Waverly, viz., the Berea grit, but it certainly belongs to the lowest of the sandstone courses of this formation."[4] The same volume contains the "Report on the Geology of Licking County," by M. C. Read, who described therein the upper Waverly of that county. The oldest division noted by Read was the *Waverly conglomerate*, which was said to be "conspicuously exposed along the south bank of the Licking in Madison and Hanover townships, presenting abrupt, precipitous bluffs 20 to 40 feet high."[5] The conglomerate was succeeded by the "olive shales," which were said to occupy "an interval of 150 to 190 feet below the Carboniferous conglomerate,"[6] and were described as composed mainly of shales, but with some "strata of massive sandstone."

---

[1] Rept. Geol. Surv. Ohio, Vol. III, Pt. I, p. 638.

[2] *Ibid.*, p. 639.

[3] *Ibid.*, p. 642.

[4] *Ibid.*, p. 642.

[5] *Ibid.*, p. 360.

[6] *Ibid.*, p. 359.

In July 1878 Professor L. E. Hicks, of Denison University, announced "the discovery [of] an unmistakable outcrop of Cleveland shale [which] exists two miles east of Sunbury in Delaware county, southern [central] Ohio, on the land of Horace Whitney. It lies *above* the calcareous sandrock of the Sunbury quarries, which Professor N. H. Winchell, a special assistant of the Ohio geological survey, identified as *Berea grit.* My discovery *demonstrates* the incorrectness of that identification, and raises a strong presumption, amounting almost to a certainty, that he was equally wrong in respect to his Berea grit in Morrow and Crawford counties."[1] Professor Hicks made no reference to the classification of the Waverly and identification of the Cleveland shale in Franklin county by Dr. Orton, and on the other hand Dr. Orton did not mention Professor Hicks' papers in any of his publications so I am unable to state which article has priority. The September number of the same periodical contained a classification of the Waverly group in central Ohio by Professor Hicks, which was stated to include the rocks lying between the Huron shales and the base of the Coal-measures. The classification is as follows:

	Feet thick
5. Licking shales	100–150
4. Black Hand conglomerate and Granville beds	85–90
3. Raccoon shales	300
2. Sunbury black slate	10–15
1. Sunbury calciferous sandrock[2]	90–100

The following year Dr. Orton published a "Note on the Lower Waverly Strata of Ohio" in which for the first time the Waverly black shale of southern Ohio was correctly correlated with the black shale directly above the Berea grit in northern Ohio for which the name Berea shale was proposed. This furnished the key for the correct correlation, between northern and southern Ohio, of the lower formations of the Waverly series, which was summarized in the following table:

---

[1] Am. Jour. Sci., and Arts, 3d ser., Vol. XVI, p. 71.

[2] *Ibid.*, p. 216.

Northern Ohio		Southern Ohio	
Cuyahoga shale Upper beds fossiliferous	150–250 ft.	Shale and sandstone Upper beds fossiliferous	300–400 ft.
(Berea shale) Included by Newberry with Cuyahoga	10 ft.	Waverly black shale	15 ft.
Berea grit	60 ft.	Waverly quarries and overlying blue shale	60 ft.
Bedford shale	75 ft.	Waverly shale	90 ft.
Cleveland shale		Great black shale[1]	

In 1888 Dr. Orton published a general classification of the Waverly group which he considered as composed of the Bedford shale, the Berea grit, the Berea shale, the Cuyahoga shale, and the Logan group. The Cuyahoga shale, however, was restricted to the shales and fine-grained sandstones between the Berea shale and the base of the conglomerate and sandstone forming the upper part of the Waverly. This upper division was called the Logan group which was said to consist of the Waverly conglomerate and Logan sandstone of Andrews as found in Hocking, Fairfield, and Licking counties. To the north the olive shales of Read in Knox and Richland counties were correlated with the Logan sandstone.[2] The same classification was republished by Dr. Orton in his last report for the Ohio survey.[3]

In 1888 Professor C. L. Herrick, who had studied the paleontology and stratigraphy of the Waverly series of central Ohio more thoroughly than any of the former observers, published his conclusions. Professor Herrick had also studied the Waverly of northern and southern Ohio and rocks of similar age in Pennsylvania and western New York, so that his classification was not intended to be confined to the rocks of central

---

[1] *Ibid.*, Vol. XVIII, p. 139.

[2] Rept. Geol. Surv., Ohio, Vol. VI, pp. 33–42.

[3] *Ibid.*, Vol. VII, 1893 [1895], pp. 26–35.

Ohio. The upper part of the series he correlated with the formations of the Mississippi valley and two quite persistent conglomerate horizons were named Conglomerate I and II.[1]

The classification is as follows:

Cuyahoga or Waverly series	Logan	Keokuk, 100–150 ft. Burlington
	(Conglomerate II) Kinderhook, 50–60 ft. (Conglomerate I)	
Berea or Transition series (Western equivalent of Upper Chemung)	Waverly shale, 40 ft. Berea shale, 200–400 ft. Berea grit, 50–60 ft. Bedford shale, 50 ft. Cleveland shale (local), 50 ft.	
Erie shale, Eastern or typical Chemung (lower part), 100 ft.[2]		

In the above classification the Berea shale included Dr. Orton's Berea shale and all of his overlying Cuyahoga shale except its fossiliferous upper 40 feet which, extending to the base of Conglomerate I, was called the Waverly shale.

In 1889 Dr. Newberry stated that the Waverly group "where best seen, as in northeastern Ohio, ... is about 500 feet thick, and fills the interval between the Erie shale (Chemung) below and the Carboniferous conglomerate above."[3] The following classification of the Waverly group was given:

	Average thickness feet
1. Cuyahoga shale	230
2. Berea shale	20
3. Berea grit	60
4. Bedford shale	75
5. Cleveland shale[4]	50

---

[1] Bull. Sci. Lab., Denison University, April 1888, Vol. III, p. 24; see also section on p. 26.

[2] *Ibid.*, December 1888, Vol. IV, pp. 105, 106. The zones of these formations with their characteristic fossils and thickness are given in detail on pp. 99–101.

[3] Mon. U. S. Geol. Surv., Vol. XVI. The Paleozoic Fishes of North America, p. 120.

[4] Loc. cit.

It will be noticed that Dr. Newberry accepted the separation of the Berea shale from the Cauyhoga shale; but did not accept the reference of the Cleveland shale to the Ohio shale. This point he discussed quite fully and stated that the union of the Cleveland, Erie, and Huron shales to form the Ohio shale seemed unwarranted.[1] Dr. Newberry referred to Professor Hicks announcement of the discovery of the Cleveland shale in Delaware county, saying in conclusion: "I think he has found there the Berea shale, which lies immediately above the Berea grit."[2]

In 1891 Professor Herrick reviewed the general stratigraphy of the Waverly series, commencing with the Bedford shale. The lower boundary of the Waverly, however, he thought "must be found in the Berea grit, which . . . . is a sharply limited and easily recognizable horizon throughout Ohio."[3] The Berea grit came next, followed by the Berea shale, which, he states, is a term "conveniently applied to the thin band of bituminous shale above the grit, and perhaps should not be extended (as the writer has done in a previous paper) to the gray and blue shales above."[4] For the overlying rocks he used the name Cuyahoga shale in the sense in which it was used by Dr. Orton, except that the upper 40 feet, as in the previous paper, was called the Waverly shale. This division was stated to be stratigraphically continuous with the Cuyahoga shale which it also resembled lithologically, but paleontologically it more closely resembled the succeeding division or Kinderhook. The last division was called the Burlington and Keokuk.

REVISED CLASSIFICATION

This concludes the review of all the important papers published concerning the classification of the Waverly series of central Ohio. As a result of this study followed by an examination of the formations in the field, the writer proposes the following classification for the Waverly series of central Ohio.

---

[1] *Ibid.*, p. 128.

[2] *Ibid.*, p. 129.

[3] Bull. Geol. Soc. Amer., Vol. II, p. 35.

[4] *Ibid.*, p. 35.

No attempt is made, however, to correlate the formations with those of the sub-Carboniferous of other states:

	Feet
6. Logan formation (Andrews)	115
5. Black Hand formation (Hicks)	40–(120 ?)
4. Cuyahoga formation (Newberry)	275–300
3. Sunbury shale (Hicks)	10–15
2. Berea grit (Newberry)	40
1. Bedford shale (Newberry)	85+

Bedford shale was named by Newberry in 1870[1] from the outcrops at Bedford, southeast of Cleveland, at which place, he later states, the best exposure occurs.[2] The term "Bedford rock" appears in Richard Owen's description of the geology of Lawrence county, Indiana, published in 1862;[3] but it was not used as the name of a geological division. This interpretation is apparently confirmed in the subsection of the report devoted to the general description of the sub-Carboniferous limestone where the term "Middle or Lawrence—Crawford sub-Carboniferous limestone"[4] is proposed, a name evidently employed to denote a geological division. Mr. E. R. Cumings, of Indiana University, informs me that the Bedford oölitic limestone belongs in this division.[5] Writers since Owen have used the terms "Bedford stone," "Bedford oölitic stone," and other names for the rock, which was finally excellently described in 1896 by Hopkins and Siebenthal under the formation name of the "Bedford oölitic limestone."[6] It is the opinion of the writer, however, that the term "Bedford shale" used by Dr. Newberry as the name of a formation in 1870 is the one that should stand and the Indiana formation name of Bedford oölitic limestone should be dropped. Since the above was written Mr. E. R. Cumings has proposed the name, Salem limestone, for the Bedford oölitic limestone of Indiana.[7]

[1] Geol. Surv. Ohio, Pt. I, 1870, p. 21.

[2] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, 1873, p. 189.

[3] Rept. Geological Reconnoissance of Indiana during 1859 and 1860, p. 137.

[4] *Ibid.*, p. 125.

[5] Letter, January 13, 1901.

[6] Twenty-first Ann. Rept. Ind., Dept. Geol. and Nat. Resources, pp. 291, 298.

[7] Am. Geol., Vol. XXVII, March 1901, p. 147.

This formation succeeds the Ohio shale, and as the Cleveland and Erie shales are supposed not to extend to central Ohio it probably rests on the Huron shale in Franklin county. The lower part of the formation in this county is well shown on the eastern bank of Big Walnut Creek east of Central College where the following section occurs:

	Thickness feet	Total thickness feet
No. 7. Till and soil - - - - - - - -	5	87½
6. Fine green argillaceous shale. *Bedford shale*	7	82½
5. Mixed chocolate and greenish shale, mostly olive color - - - - - - - -	7½	75½
4. Chocolate shale composed of fine clay -	21⅔	68
3. Fine green to olive argillaceous shales. Near base blocky shales containing fossils. *Base of Bedford* - - - - - -	17⅓	46⅓
2. Fine black shales containing small concretions. *Huron shale* - - - - - -	24½	29
1. Covered to level of Big Walnut Creek -	4½	4½

The greater part of the formation is shown on Rocky Fork, commencing about one and a half miles east of Gahanna and continuing up the creek for a mile. About one fourth mile up the creek from the ford on the north and south road is an outcrop, on the southern bank, of three feet of black shale which is nearly at the top of the Huron shale. A short distance farther up the creek is a higher bank which gives the following section:

	Thickness feet	Total thickness feet
No. 3. Till - - - - - - - - - - -	6½	28¾
2. Fine chocolate shales of the Bedford - -	7	22⅓
1. *Bedford shales.* The upper part is somewhat sandy but the grains are very fine, and the lower part is composed of greenish to bluish argillaceous shale. Creek level - - - -	15⅓	15⅓

At the second bluff to the west of the private bridge is the following section:

	Thickness feet	Total thickness feet
No. 2. Till - - - - - - - - - - -	7⅔	36
1. Chocolate argillaceous shale which weathers to a red clay. *Bedford shale.* Creek level -	28⅓	28⅓

To the east of the bridge the base of the till is much lower than on the western side and there is a marked line of unconformity between the till and Bedford shale. Two hundred and twenty-five feet east of the above section is the following, which shows an irregular surface on which the till was deposited:

	Thickness feet	Total thickness feet
No. 2. Till with beds of sand	49⅓	54
1. Bedford chocolate shale. Creek level	4⅔	4⅔

The covered interval between this bank and the next one is extensive enough to hide the top of the chocolate shale and the bluff is composed of grayish shales of the upper Bedford capped by the Berea sandstone. The following section is shown on the western bank of the creek below a tree:

	Thickness feet	Total thickness feet
No. 4. Till	5	56½
3. Grayish sandstone layers about one foot thick. *Berea sandstone*	14	51½
2. Sandy, fine-grained shales with argillaceous ones above and below	9¾	37½
1. At the top a sandy concretionary layer 2 ± feet thick. Shales mostly grayish and argillaceous. In the lower part are spots of reddish-gray shale somewhat similar to the mottled shale No. 5 east of Central College. Level of creek	27¾	27¾

The Bedford shale includes the red band from 15 to 20 feet in thickness, which Dr. Orton, in his report on Franklin county, considered the upper part of the Huron shale;[1] the gray shale between the red and black Huron shales which was not mentioned in the county report; and the Waverly shales.[2]

2. *Berea grit* was named by Dr. Newberry in 1870, from the large quarries at Berea, southwest of Cleveland.[3] It is well shown on Rocky Fork, to the north of the outcrops of the Bedford shale and on the banks of Big Walnut Creek about one mile northeast of Sunbury, Delaware county. There are beautiful examples of ripple marks in the sandstone at both of these localities. On the eastern bank of Rocky Fork is an exposure of 31½

[1] *Ibid.*, Vol. III, Pt. I, p. 638. [2] *Ibid.*, p. 639. [3] Geol Surv. Ohio, Pt. I, p. 21.

feet of gray, thin bedded Berea sandstone, some of the layers a foot or more in thickness, with some partings of clay shale below which are 8 feet of bluish Bedford shales partly argillaceous and partly arenaceous, while in the upper part are thin layers of sandstone. The thickness of the Berea sandstone on this creek is about 40 feet and in the upper part at the highway is a small quarry. On the western bank of the Big Walnut between the railroad and highway bridges, one mile northeast of Sunbury, there is from 26 to 30 feet of it shown in the vertical cliff. This formation is called the "Waverly quarry system" in the report on Franklin county,[1] and the "Sunbury Calciferous sandrock" by Professor Hicks.[2]

3. *Sunbury shale* was named by Professor Hicks in 1878, from outcrops on Rattlesnake Creek on the present farm of Amos Whitney, about two miles east of Sunbury. North of the Whitney house there is an outcrop of 3½ feet of this black shale on the northern bank of the creek, and it may be seen at irregular intervals for some distance down the stream. A single specimen of a *Lingula* was the only fossil found, but the lower part of the shale is concealed and the top of the Berea grit crosses the creek a little below the house of Mr. W. P. Swallow. There is a much better exposure on Rocky Fork, in Franklin county, where the contact of the shale and Berea is shown just above the highway bridge on the David Meyers farm. The lower 2 feet of the very fossiliferous shale is exposed, containing abundant specimens of *Lingula melie* Hall, and *Orbiculoidea Newberryi* Hall, together with fragments of fish bones and teeth. Farther up the creek 8 + feet of the shale is shown on the western bank resting on the Berea grit.

This shale was first inappropriately named the "Waverly black slate" by Andrews in 1870[3] because the term Waverly had already been used for the larger division which includes this shale. Geological nomenclature is being revised for the purpose of eliminating and preventing the duplication of geographic names of stratigraphic divisions of the same or different rank. The name Berea shale, proposed by Dr. Orton in 1879,[1] is excluded, first, by the law of priority, since Sunbury shale was published and defined by Professor Hicks the preceding year, and second, because Berea had been used in 1870 by Dr. Newberry for the name of a formation. The division termed the Cleveland shales in the report on Franklin county is the Sunbury shale.[2]

---

[1] *Ibid.*, Vol. III, p. 639.

[2] Am. Jour. Sci., 3d ser., Vol. XVI, p. 216.

[3] Geol. Surv. Ohio, Pt. II, 1870, p. 66.

4. *Cuyahoga formation* (shale) was the name given by Dr. Newberry in 1870[3] to "the uppermost member of the Waverly group" and was described as crossing Cuyahoga county and forming the banks of the Cuyahoga River to the Cuyahoga Falls.[4] Originally the Sunbury shale constituted the lower part of this formation, and in 1888 Dr. Orton separated the coarser deposits of conglomerate and sandstone in the upper part of the Waverly, as found in central and southern Ohio, from this formation, under the name of the Logan group,[5] and said this "upper member of the series [Waverly] is wanting in the Cuyahoga Valley, or is at least very inadequately represented there."[6]

Professor Herrick in 1891 from paleontological and stratigraphical evidence showed that this upper part of the Waverly is wanting in northern Ohio, and said: "We can positively assert that the Cuyahoga shale as represented in the northern tier of counties is identical with that part of the Waverly lying below Conglomerate I . . . . of central Ohio. The fossiliferous horizons of Granville, Newark, Rushville, and Winchell's Division 4, on the Ohio River, are all above the top of the Cuyahoga."[7]

Finally, Professor Herrick stated in 1893 that in the "northern localities the calcareous, concretionary layer, which has yielded so abundant a fauna in central Ohio, was discovered at a distance of 40 feet beneath the Coal Measure conglomerate and most of the characteristic species re-collected. This served to settle the question conclusively except for the few feet above this horizon."[1]

---

[1] Am. Jour. Sci., 3d ser., Vol. XVIII, p. 138.

[2] Loc. cit., pp. 639, 642.

[4] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, p. 185.

[3] Geol. Surv. Ohio, Pt. I, p. 21.

[5] *Ibid.*, pp. 37, 39.

[6] *Ibid.*, p. 39.

[7] Bull. Geol. Soc. America, Vol. II, p. 37. See also the section of Cuyahoga Valley and Bedford, on p. 40, where it is stated that "This entire series [upper part of the Waverly] is absent in the northern tier of counties to the base of Conglomerate I."

The present writer considers the Cuyahoga shales of central Ohio as composed of the shales and sandstones occurring between the top of the black Sunbury shale and the base of the coarse deposit called by Professor Herrick Conglomerate I. In this formation, therefore, is included the 40 feet of fossiliferous shales immediately underlying Conglomerate I of Professor Herrick which he called the Waverly shale.[2] Should a separation of this shale from the Cuyahoga prove necessary it would require a different name, because Waverly had already been used—first, as the name of a series; second as the name of the conglomerate in central and southern Ohio; third, as the name of the black shale in southern Ohio; fourth, as the name of the sandstone in the vicinity of Waverly; and fifth, the identical term Waverly shale by Dr. Orton for the lowest division of the series in southern Ohio.[3]

This formation was called the Raccoon shales by Professor Hicks, who said: "It appears in force all along Raccoon Creek and its tributaries, and extends westward into Franklin and Delaware counties."[4] Its thickness was estimated by Professor Hicks as 300 feet, while Professor Herrick stated that "the Cuyahoga proper is never more than 200 feet thick."[5]

In central Ohio the Cuyahoga formation is composed largely of bluish to grayish shales and buff sandstones which are fairly well exposed on Moot's Run and other streams in the western and central parts of Licking county.

---

[1] Rept. Geol. Surv. Ohio, Vol. VII, 1893, pp. 502, 503.

[2] Bull. Denison Univ., Vol. IV, 1888, p. 107.

[3] Rept. Geol. Surv., Ohio, Vol. II, Pt. I, 1874, pp. 619, 648; and Figs. 1 and 2 of the report on Pike county.

[4] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 219.

[5] Bull. Geol. Soc. Amer., Vol. II, 1891, p. 38.

5. *Black Hand formation* (conglomerate) is the name given by Professor Hicks in 1878 to the deposits of coarse sandstone and conglomerate exposed at Black Hand in the gorge of the Licking River and about Hanover.[1] Both of these localities are in Hanover township, in the eastern part of Licking county. We find, as in the case of most conglomerates, that when this formation is followed for some distance there are quite decided differences in the lithologic character of the rocks. In the vicinity of Newark and Granville they are mainly sandstones, with some layers of shales and two comparatively thin strata of conglomerates. Professor Hicks states that these beds are well exposed at Granville and are only a local modification of the Black Hand conglomerate, and for convenience he designated them "the Granville beds."[2] Professor Andrews in 1870 called this division the Waverly conglomerate;[3] but this name was preoccupied, because Waverly had already been used for the name of the series. He correlated the conglomerate at Black Hand with that of the Waverly and gave its thickness at that locality as probably 50 or 60 feet.[4]

At Havens' quarries, on the farm of Mr. G. W. Havens, one and one half miles southeast of the central part of Newark, is a good exposure of the sandstone phase of this formation. The section begins in the conglomerate stratum on the bank of Quarry Creek below the quarries, where an excavation has been made in prospecting for gold, and continues to the top of the bank above the quarry on the eastern side of the run. The quarry on the western side of the creek is shown in Fig. 1, the lower part of which is in the Black Hand and the upper the Logan formation.

---

[1] Amer. Jour. Sci., 3d ser., Vol. XVI, pp. 216, 217.

[2] *Ibid.*, p. 218.

[3] Geol. Surv. Ohio, Pt. II, p. 135, and on the explanation of the "Section on Hocking River" of the "Map showing the Lower Coal Measures."

[4] *Ibid.*, p. 79.

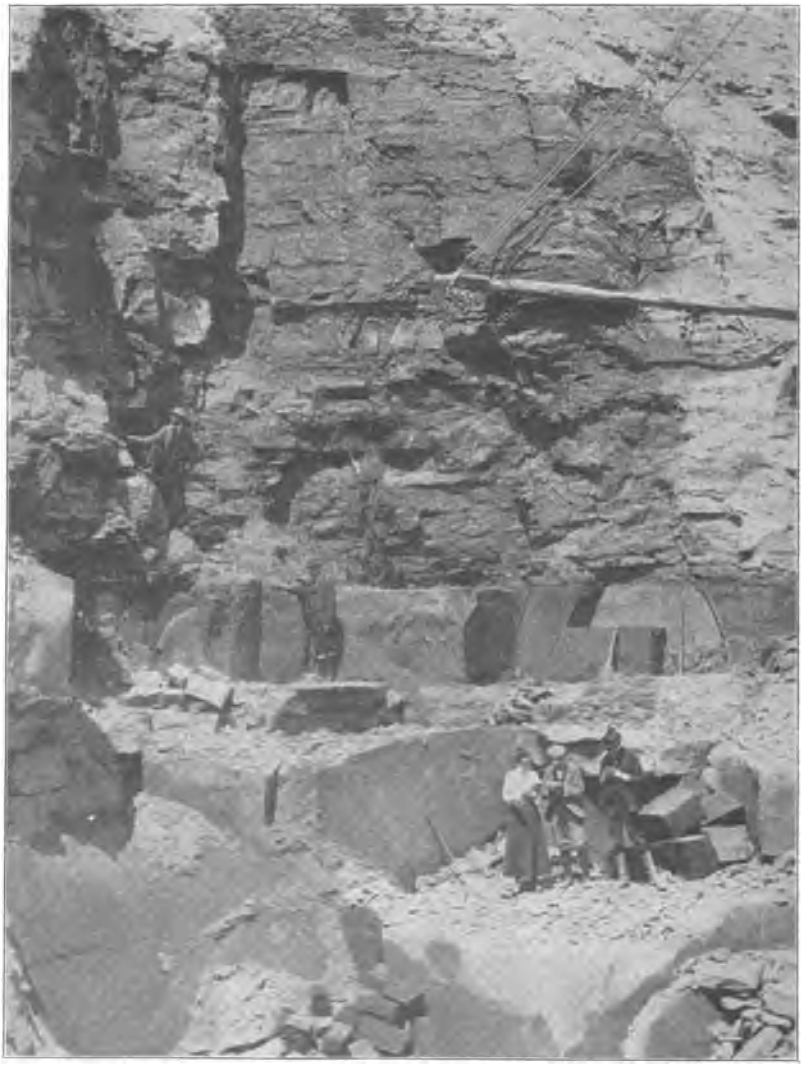


FIG. 1.—Havens quarry on the western bank of the stream. The lower part shows the massive sandstone of the Black Hand formation, the top of which is Herrick's Conglomerate II, indicated by the two upper students. Succeeding Conglomerate II the lower part of the Logan formation is shown.

SECTION AT HAVENS' QUARRY

		Thickness feet	Total thickness feet
No. 9.	Till and soil	2	75
8.	Alternating shales and sandstone	14½	73
7.	Massive buff sandstone splitting into many layers	16	58½
6.	Bluish argillaceous shales	4½	42½
5.	Conglomerate stratum No. II of Herrick; average thickness 11 inches	1	38
4.	Bluish fossiliferous shales containing numerous specimens of *Spirophyton* and other fossils; was called the "Allorisma layer" by Herrick	6½	37
3.	Grit containing a few fossils	½	30½
2.	Light gray to buff fine-grained sandstone, which is called freestone and quarried. This forms a massive zone which splits into several layers. The upper 8 feet of this zone is shown in this quarry, and, at the base in the gold-mine opening, nearly 3 feet of drab argillaceous shale, below which is 3¼ feet of coarse-grained buff sandstone. In the Havens quarry, on the western side of the creek, nearly 20 feet of this sandstone is shown, and in the Vogelmeier quarry, one and one half miles south of Newark, 27 feet of sandstone, separated by a 5-inch bluish shaly layer 9 feet below the top. In certain layers of this sandstone fossils are common, especially *Syringothyris cuspidatus* (Martin).		
1.	Conglomerate stratum, 3 feet thick. Sandstone parting, 7 inches. Massive conglomerate with quite large pebbles, which are coarser than in the upper layer. Level of creek (Conglomerate No. I of Herrick)	5	5

From the freestone No. II of the above section the following species were collected:

1. *Syringothyris cuspidatus* (Martin) (c).
2. *Spirifer Winchelli* Herrick.
3. *Crenipecten Winchelli* (Meek) (c).
4. *Platyceras Hertzeri* Winch (r).
5. *Chonetes pulchella* Winch (rr).
6. *Rhipidomella* (*Orthis*), cf. *Michelina* L'Eveillé (c).

7. *Cryptonella eudora* Hall (rr).
8. *Camarotœchia marshallensis* (A. Winch) ? (rr)

The Allorisma shales No. IV contain the following species:

1. *Allorisma ventricosa* Meek (rr).
2. *Sanguinolites* (?) *obliquus* Meek (r).
3. *Sanguinolites æolus* Meek (r).
4. *Sanguinolites* sp.
5. *Camarotœchia marshallensis* (Win.) (?) or *C. Cooperi* Shum. (?)
6. *Allorisma Winchelli* Meek (c).
7. *Sanguinolites naiadiformis* Winch. (r).
8. *Prothyris Meeki* (Winch) (r).
9. *Spirophyton* cf. *crassum* Hall (c).
10. *Syringothyris cuspidatus* (Martin) (rr).
11. *Liopteria* sp. (rr).
12. *Discina* (*Orbiculoidea*) *pleurites* (Meek) (?) (rr).

Professor Andrews did not definitely indicate the boundaries of the Waverly conglomerate; neither did Professor Hicks those of the Black Hand conglomerate and Granville beds. The thickness of the conglomerate near Hanover was given as from 85 to 90 feet,[1] and that of the Granville beds as from probably 25 to 111 feet.[2]

The Fucoid layer (No. 4c) of Hicks' Granville beds is the same as the "Allorisma layer" of Professor Herrick's and No. 4 of the Havens section. Division No. 2 of Professor Herrick's, which he called the Middle Waverly or Kinderhook, was clearly defined by Conglomerate No. I at the base and Conglomerate No. II at the top,[3] and by its fossils correlated with the Kinderhook formation of the Mississippi valley. This formation is apparently quite well marked by these two conglomerate strata in the vicinity of Newark, and Professor Herrick identified Conglomerate II in sections from Ashland county to Sciotoville on the Ohio River,[4] and later states that the Allorisma shale is "very persistent and well limited, even when the Conglomerate (No.

---

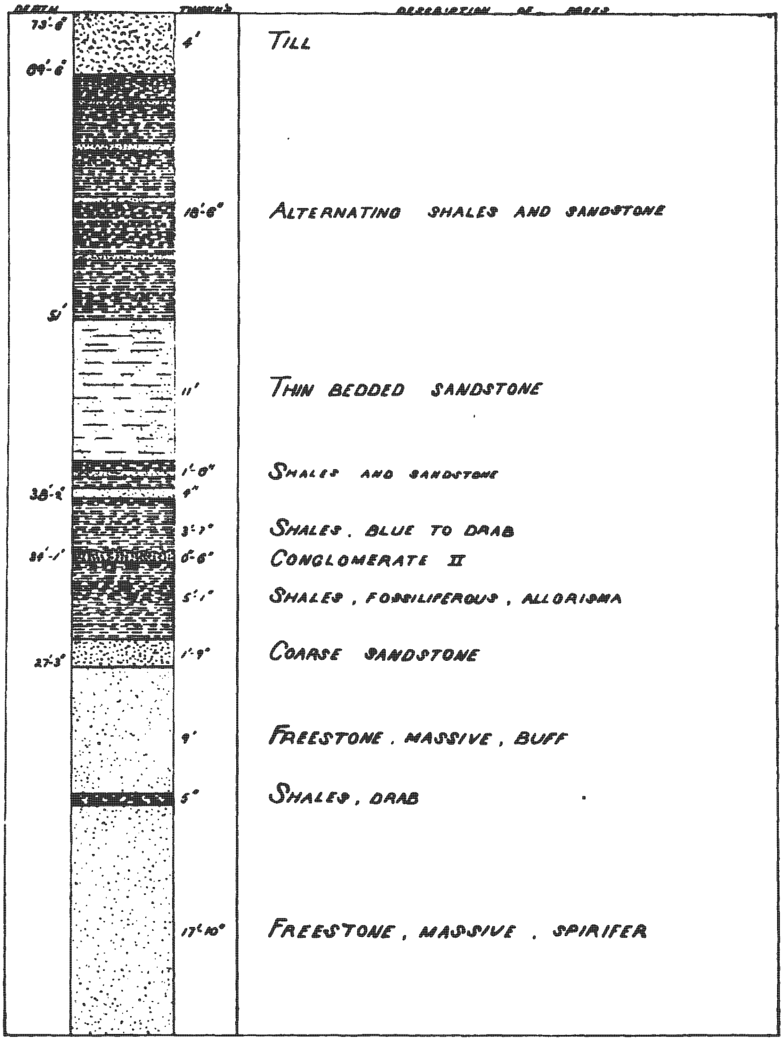
[1] Am. Jour. Sci., 3d ser., Vol. XVI, p. 217.

[2] *Ibid.*, p. 218. The statement is not clear, and 85 feet possibly represents the minimum thickness.

[3] Bull. Denison Univ., Vol. IV, 1888, pp. 105, 106.

[4] *Ibid.* See sections on p. 102.

VOGELMEIER QUARRY, NEWARK, OHIO.



C.H.FLORY.

FIG. 2.—Section of Vogelmeier quarry, southeast of Newark, showing a part of the Black Hand and Logan formations. Conglomerate II is considered the line of division between them.

II) is absent, having been traced from Sciotoville to the northern exposures in Wayne county."[1] Conglomerate No. I seems less persistent than No. II, but below the freestone there are generally thick shales, so that the base of the formation is quite distinct stratigraphically.

In the vicinity of Hanover and in the gorge of the Licking River at Black Hand are excellent exposures of the conglomerate phase of the formation. Below Hanover, on the western side of Rocky Fork, is a fine cliff of the conglomerate 80 feet high, which is shown in Fig. 3, while apparently its top, as shown by partial exposures in the field above the brow of the cliff, is some 35 feet higher. Professor Hicks gave the thickness of the Black Hand conglomerate at Hanover as from 85 to 90 feet,[2] and Professor Herrick reported that in the region about Clay Lick station, in Hanover township, "is a great development of the conglomeratic phase of the Waverly. One half mile east of Clay Lick there is a nearly continuous exposure of about 100 feet of alternating conglomerate and coarse sandstone of prevailingly red color."[3]

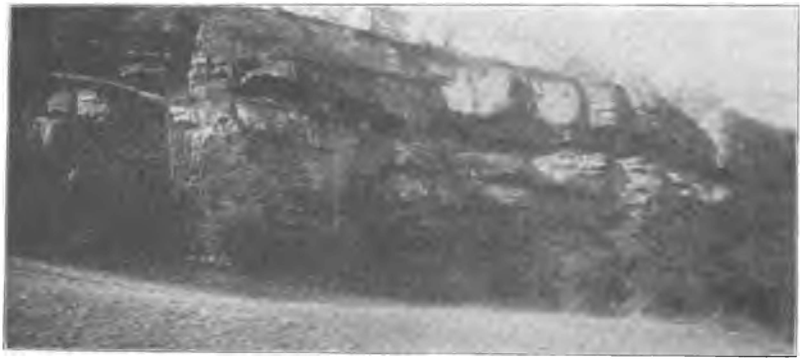


FIG. 3.—Ledge of Black Hand conglomerate below Hanover.

---

[1] Bull. Geol. Soc. America, Vol. II, 1891, p. 38.

[2] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 217.

[3] Bull. Sci. Lab. Denison Univ., Vol. II, 1887, p, 15.

To the east of the Hanover railroad station is a cut in which the contact of the Black Hand conglomerate and overlying Logan sandstone is nicely shown. To the south of the cut and highway is the quarry of the Hanover Pressed Brick Co. in the shales of the Logan formation. The section from the railroad to the top of the quarry is as follows:

		Thickness feet	Total thickness feet
No. 4.	Mainly blue to drab argillaceous shales with some bands of sandstones which vary from 7 inches to perhaps a foot in thickness -	20	92
3.	Covered - - - - - - - - -	18	72
2.	Buff shaly thin bedded sandstones containing fossils which are well shown in the upper part of the railroad cut in the vicinity of the highway bridge. Lower part of the *Logan sandstone* which is separated by quite a sharp line from the massive grit to conglomerate below. There are some thin layers of conglomerate near the base of the Logan sandstone.	22	54
1.	Massive grit to conglomerate which forms the lower portion of the cut. Part of the rock is a buff grit and the remainder a conglomerate some of the pebbles of which are quite large.	32	32

BLACK HAND CONGLOMERATE

The Black Hand conglomerate named from the cliffs in the gorge of the Licking River, known as the Licking Narrows, begins a short distance above the station of Black Hand on the Baltimore and Ohio Railroad.[1] On the north side of the river rather more than a quarter of a mile above the bridge are two conspicuous cliffs, the lower one called Red Rock and the upper one Black Hand which is shown in Fig. 4. On the southern side of the river is a railroad cut which shows finely the contact of the Black Hand conglomerate and the Logan sandstone. To the west of the cut at a distance of about one half mile from the station is a prominent cliff in one part of which is the E. H.

---

[1] For a description of the topography of this region and the former as well as the present gorge of Licking River, see Professor W. G. Tight's paper in Bull. Sci. Lab., Denison Univ., Vol. VIII, Pt. II, pp. 36–43, and Pls. I, II.

Evertts & Co. quarry for glass sand. The following section was measured at this locality from the level of Licking River to the top of the cliff.

SECTION OF SOUTHERN BANK OF LICKING RIVER AT EVERTTS & CO. QUARRY

		Thickness feet	Total thickness feet
No. 6.	Till	7	101
5.	Thin, irregular bedded, drab or bluish sandstone and bluish argillaceous shales. In places at the bottom is a 3-inch clay shale resting on the massive conglomerate with a sandstone to conglomerate layer above. Lower part of the *Logan sandstone*	22	94
4.	A coarse conglomerate stratum at the top of the conglomerate which in places is 11 inches thick. The top of the *Black Hand conglomerate*	1	72
3.	Gray to drab coarse grit, which in places is a conglomerate that is worked for glass sand. This forms the upper part of the main cliff	21	71
2.	Coarse grit and conglomerate to the base of the cliff at the Crusher	16	50
1.	Mostly covered bank below the Crusher but all in the conglomerate as shown by exposures a little farther down the river. Level of Licking River	34	34

6. *Logan formation* (sandstone) was named by Professor Andrews in 1870 from outcrops in Hocking county near Logan,[1] and was stated to overlie the conglomerate at Black Hand and to extend down the Licking Valley "to a point between Pleasant Valley and Dillons Falls."[2] This division was named the Licking shales by Professor Hicks, who states that they are well developed in the hills bordering Licking River from Newark to Black Hand, 100 to 150 feet in thickness, and "lie 70 to 80 feet above the water level, forming the middle of the slope of these hills, the base being composed of the massive Black Hand conglomerate and the upper slopes and summit of the various strata of the Coal

[1] Geol. Surv. Ohio, Part II, pp. 76, 79.

[2] *Ibid.*, p. 79.

Measures."[1] This formation is Division 3, or the Upper Waverly of Professor Herrick, which he gave as 80 feet in thickness in Licking county and which, from the fossils, he correlated with the Burlington and Keokuk of the Mississippi valley.[2]

In 1888 Dr. Orton united the Waverly conglomerate and Logan sandstone of Andrews to form the Logan group.[3] If it be advisable to make one formation of these two divisions, the above name is inappropriate because the Logan sandstone of Professor Andrews clearly referred to the upper division only, as has been noted by Professor Herrick.[4]

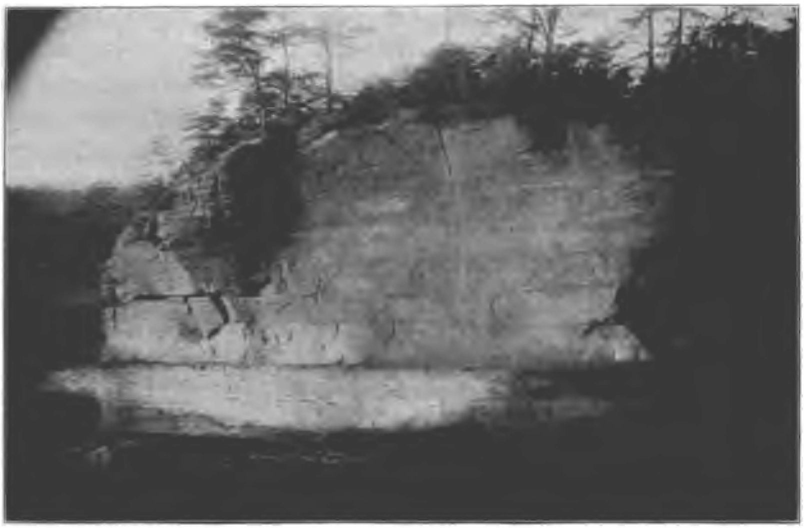


FIG. 4—Black Hand rock in the gorge of Licking River.

The above ruling is believed to represent the position of the United States Geological Survey, as shown by the following quotation from a recent letter of Mr. Bailey Willis, assistant in geology to the Director of the United States Survey and Geologist in charge of Areal Geology, to whom these questions in nomenclature are referred:

---

[1] Am. Jour. Sci., 3d ser., Vol. XVI, 1878, p. 216.

[2] Bull. Denison Univ., Vol. IV, 1888, pp, 99, 100.

[3] Rept. Geol. Surv., Ohio, Vol. VI, p. 39.

[4] Bull. Geol. Soc. Amer., Vol. II, 1891, p. 38.

> The survey distinctly recognizes the right of priority, that is to say, the name first applied to a well defined geologic unit is to be preferred. The qualifying conditions, on account of which the name may be rejected and one of later application used, are (1) that the name has been previously applied to some other unit, and (2) that the unit to which the name was applied was not well defined.
>
> Thus, in the case which you cite, the term Waverly conglomerate (Andrews) would not hold if Waverly had previously been used for something else, and by application of the same rule Waverly series should be discarded if Waverly conglomerate had priority. The Logan group (Orton) should not stand as opposed to Logan sandstone.
>
> In these questions there is often a personal element which makes it a matter of regret that some desirable name should not be adopted, but we feel that the advantages of clearness and definition in science must be superior to such conditions, and that the rule should be rigidly applied.[1]

Dr. George H. Girty, of the United States Geological Survey, who has been engaged for several years in a thorough study of the stratigraphy and paleontology of the Waverly series in Ohio, Michigan, and Pennsylvania, concurs in regarding the upper part of the series in central Ohio as composed of two formations, as may be seen from the following quotation:

> I have seen the Logan group at Logan and vicinity and also at various points in Licking county. I quite concur with you in regard to the separateness of the two component members in central Ohio at least, and am in uncertainty as to the reasons which led Professor Orton to unite the two beds under a common name.[2]

The lower part of this formation is well shown in the Vogelmeier and Havens quarries, where Conglomorate II is succeeded by from 4½ to 6 feet of greenish-gray to bluish argillaceous shales, and these are followed by from 11 to 17 feet of quite massive buff sandstones, capped by alternating shales and sandstones, 18½ feet of which are shown at the top of the Vogelmeier quarry. There are fair exposures of the remaining part of the formation in "the gorge" to the east of the Havens quarry,

[1] Letter of December 18, 1900.

[2] Letter of January 5, 1901.

partly in the bank of the creek and partly by the roadside, where 85 feet of buff arenaceous shales to thin bedded sandstones are shown. This gives about 115 feet for the thickness of the formation, which is capped by the Coal-measure conglomerate where the road and creek emerge from the woods. In sections farther to the south and southeast the top of the Logan sandstone is defined by the base of the sub-Carboniferous limestone, named by Professor Andrews the Maxville limestone.

CHARLES S. PROSSER.

COLUMBUS, OHIO,
December, 1900.

THE USE OF BEDFORD AS A FORMATIONAL NAME

In a paper about to be published by Professor Charles S. Prosser it will be stated that the "*Bedford shale* was named by Newberry in 1870[1] from outcrops east of Cleveland at which place, he later states, the best exposures occur." It will be further stated that the term "Bedford rock" as used by Owen[2] for a portion of the Sub-Carboniferous limestone of Indiana was evidently not intended as a formation name.

In the citation of Owen's use of the term Bedford rock lies the basis for the present use of the name Bedford for the Indiana formation. In the later reports of the Indiana Geological Survey, down to the Twenty-first Annual Report, the name Bedford is not applied to these rocks; but in the Fifteenth Annual Report the name Salem rock[3] is used, though not as a formation name, and again in the Seventeenth Report, Salem is said to afford the "best exposure for study [of the oölitic limestone] from the geologist's point of view."[4] In the Fifteenth Report (*loc. cit.*) a section of the Salem Stone and Lime Company's quarry one half mile west of Salem is given as follows:

Soil and rubbish	3 feet
Dark blue, bituminous limestone (bastard)	6 "
Gray oölitic quarry stone	30 "
Blue crystalline limestone	6 "
Total	45 feet

The oölitic character of the rock is said to be especially well shown in this section.

Since the term Bedford as the name of a formation is preoccupied, having been applied to the "Bedford shale" of northeastern Ohio in 1870, the writer proposes the name *Salem limestone* for the rocks called Bedford limestone by Hopkins and Siebenthal.[1] The so-called bastard limestone of the quarrymen is to be considered as the base of the formation next above (Mitchell); and the base of the Salem formation is to be taken at the top of the Bryozoal limestone that throughout its entire extent constitutes the upper zone of the Harrodsburg limestone as defined by Hopkins and Siebenthal.[2]

---

[1] Geol. Surv. Ohio, Part I, Rept. Progress in 1869, 1870, p. 21.

[2] Geol. Recon. Indiana, 1862, p. 137.

[3] Ind. Geol. and Nat. Hist., Fifteenth Ann. Rept., p. 143.

[4] Indiana, Dept. of Geol. and Nat. Resources, Seventeenth Ann. Rept., p. 47.

In suggesting a different name for the rocks under consideration the writer is aware of the claims of Spergen hill. The latter place is, however, chiefly known as having afforded the extensive series of fossils described by Hall[3] and later redescribed and figured by Whitfield,[4] and is not so good a place for studying the stratigraphic relationships of the formation as a number of other localities. Moreover, the Spergen hill fauna is confined to parts of the formation, and in many localities would be of scarcely any service in identifying it. The oölitic character of the rock, on the other hand, while more pronounced at some places than at others, everywhere serves as a means of identification and is the character that is especially well developed at Salem. Finally, as indicated above, the name Salem has been associated with the oölitic limestones in the Indiana reports since 1885.

EDGAR R. CUMINGS.

DEPARTMENT OF GEOLOGY,
INDIANA UNIVERSITY.

---

[1] Indiana, Dept. of Geol. and Nat. Resources, Twenty-first Ann. Rept., 1896, p. 298.

[2] *Ibid.*

[3] Trans. Alb. Inst., Vol. IV; Indiana, Dept. Geol. and Nat. Hist., Twelfth Ann. Rept.

[4] Bull. Am. Mus. Nat. Hist., Vol. I, No. 3.

ON THE USE OF THE TERM BEDFORD LIMESTONE

It has not been the custom of the Indiana geologists to give local geographic names to geologic formations, and previous to the twentieth report of the state geologist (for 1895) but three or four formations had been so described. The earlier geologists were content to correlate the rocks with the formations of adjoining states and use the names already in use.

The business of quarrying the oölitic limestone grew up at a number of points. The quarry rock was recognized to be equivalent but was not known to be continuous. It was thought to exist in "deposits." Each locality was jealous of the qualities of its "deposits." So we had *White River stone*, *Elletsville stone*, *Bedford stone*, *Salem stone*, etc. In the course of time the greater development of the quarries at Bedford caused that stone to dominate the others in the market, and the Indiana oölitic limestone came to be generally known as *Bedford stone*, and as such, it has been specified by architects in more than thirty states. Its reputation having become thus established, all localities were willing to have their stone known as *Bedford stone*, and geologists were no longer embarrassed by local rivalry in giving this name to the formation.

Dr. R. T. Brown, state geologist, in a "Geological Survey of the State of Indiana," published in 1854,[1] gives a section of the rocks at the railway cut near Harristown (presumably that celebrated later as Spergen Hill), recognizing the quarry ledge with its characteristic fossils to be equivalent to that quarried at Bedford, and the same as that shipped from the northwestern part of Monroe county as *White River stone*.

Richard Owen[2] in 1862 used the term *Bedford rock*, referring to stone quarried from the formation in question at Bedford.. It may be noted here that in the Bedford region the formation is practically homogeneous and is quarried from top to bottom.

---

[1] Transactions of the Indiana State Agricultural Society, 1853, pp. 311, 312.

Geological Reconnoissance of Indiana, 1862, p. 137.

The reports of the Indiana Survey for 1869, 1870, and 1872 deal exclusively with the coal deposits. The report for 1873 mentions *Bedford stone* on pages 276, 280, 282–284, and 312. The report for 1874 does not touch upon the formation. The report for 1875 alludes to the oölitic limestone of Owen county as *white quarry stone*. In the report for 1878 an analysis of stone from Bedford is referred to in the index as *Bedford stone*.

The reports from 1880 to 1895 inclusive speak of this stone as Indiana oölitic limestone, though that from Bedford is called Bedford stone (1881, p. 31), and, as mentioned in the preceding article, that from Salem is called *Salem stone* (1885–6, pp. 143–146). So, too, it had been called *Salem stone* in the preceding report (1884, pp. 76–78).

In the report by T. C. Hopkins and the writer (1896, pp. 289–427) the oölitic limestone of the different quarries was for the first time shown to be not only equivalent but actually continuous. A single name became imperative. It was at hand. The name *Bedford oölitic limestone* was adopted rather than proposed as a new name. To have proposed a name would have raised the question of priority, and *White River limestone* would clearly have been entitled to precedence. Under the title *Bedford stone* this limestone was as well known as a geologic formation can be, over more than half the United States. The term which had been originally applied to the whole formation at one place was now extended to the formation throughout its extent.

We think that these facts justify the prior claims of Indiana to Bedford as a formation name, and that it will not be necessary to drop the term. But drop it we could not if we would, for, to the trade, *Bedford stone* it will be to the end of the chapter.

C. E. SIEBENTHAL.

NITRATES IN CAVE EARTHS

A NEW theory of the origin of nitrates in cave earths has been recently propounded by Mr. William H. Hess (JOUR. GEOL., Vol. VII, p. 2) who considers that they are the product of the nitrifying bacteria in the soil above, and that they enter the cave with the seepage through the roof and are deposited by the total evaporation of the water in the dryer parts of the cave. In other words the dry galleries and chambers of a cave serve as a gigantic natural still, catching the seepage from the surface and retaining the solids. Inasmuch as the older theory that these nitrates are leached from the bat guanos formed in the caves is on the face of it sufficient to account for the facts while difficulties arise in the application of the new theory a comparison would seem to be in order. The first and most serious objection Mr. Hess urges against the older theory is a statement that bats never go far from the mouth of the cave, while many analyses (not quoted) show that the nitrates are distributed through the dry chambers of the cave. This would seem to be decisive if rigorously verified, for if bats never went far from the entrance it would be exceedingly difficult to account for the presence of derivatives of bat guano in all dry portions of the cave. In reality, bats frequent in very large numbers remote portions of caves. Dr. O. C. Farrington, in a recent expedition through the caves of Indiana, found bats in all parts of the caves visited.[1] Mr. Hess' second objection is that the cave earth contains little or no organic matter. Two specimens in the collections of the Field Columbian Museum, one from Indiana and one from South America do contain organic matter visible on casual inspection. As the niter, according to the general opinion, is for the most part not a decomposed or altered guano but a residual clay or sand impregnated with soluble salts by seepage from bat guano, there is no reason why it should contain insoluble organic matter or more organic matter than is indicated by the amount of nitrogen and chlorine shown by Mr. Hess' analyses. This objection, apparently based on inspection of the specimens and a single analysis, cannot therefore be considered proven. The third objection made by Mr. Hess to the origin of nitrates in the cavern itself is that while the cave earth and the bat guano contain approximately equal quantities of phosphates, the soluble phosphate is much less in the underlying earth than in the overlying guano. This, however, is merely an illustration of a phenomenon with which all phosphate manufacturers are familiar, viz., the "reversion" of the soluble to the insoluble phosphate by virtue of which a very large percentage of the "available" or soluble acid calcium phosphate of a "superphosphate" when applied to the soil, changes to various insoluble phosphates.[1] It does not appear, then, that any of the above objections are in any sense conclusive.

---

[1] Field Columbian Museum Publication 53, p. 244.

In support of the external origin of the nitrates, Mr. Hess calls attention to the fact that the leachings from the surface subsoil contain nitrates in small quantity. He also attempts to show by analyses that the soluble portions of the niter earth might be the concentration of the leachings from surface soils, although the figures he gives appear to prove the reverse. Inasmuch as both the niter earth and the surface soil are both (in the Kentucky and Indiana caves) residual soils from limestone, contaminated with organic matter, a general similarity in consequence of similarity of origin is to be expected and is found. But if the soluble salts of the niter earths are the soluble salts transported from the overlying soil, more than a general resemblance should appear. After due allowance is made for compounds which will not redissolve the two should be practically identical if the analyses correctly represent the average constitution of the mixtures in question. As printed, Mr. Hess' analyses do not admit of ready comparison. If the analysis which he gives (p. 131) of subsoil over Mammoth Cave and of the cave earth directly below are recalculated so as to indicate the percentage composition of the soluble portion (on the assumption that the analyses are complete) they compare as follows:

---

[1] WYATT: Phosphates of America.

SALTS LEACHED FROM SUBSOIL AND FROM CAVE EARTH, MAMMOTH CAVE

	Na_2O+K_2O	CaO	SO_3	P_2O_5	N_2O_5	NH_4
1. Subsoil.........	15.32	9.58	28.72	tr.	36.17	10.21
2. Cave earth......	28.94	20.54	42.10	0.003	8.30	00.001

The resemblance is purely qualitative, and it is very evident that the second substance could not be formed by the evaporation of a solution of the first as the theory requires. The water which enters the cave forms stalactites and stalagmites and, therefore, must carry carbonate of lime. In the aqueous extract from the subsoil, considered below, the bases are saturated with nitric and sulphuric acid and hence it contains no carbonates. This analysis therefore does not represent the waters which enter the cave. It is most probable that these waters after leaving the subsoil take up carbonate of lime and other material while passing through the rock roof and enter the cave with the composition of the drip water whose analysis is given by Mr. Hess (*loc. cit.*, p. 132).

From the analysis of waters dripping into Mammoth Cave made by Mr. Hess, the figures below have been derived calculating the ratio of certain salts for comparison with the soluble salts from the cave earths of Mammoth and Saltpeter Caves, also recalculated from Mr. Hess' analyses.

SALTS LEACHED FROM CAVE EARTH COMPARED WITH CORRESPONDING SALTS FROM DRIP WATER

	K_2O+Na_2O	CaO	SO_3	P_2O_5	Cl	N_2O_5	NH_4
Certain salts from drip water, Mammoth Cave...........	23.24	42.37	22.18	tr.	3.83	8.06	0.06
Cave earth, Mammoth Cave..	27.23	19.91	40.56	......	5.26	6.95	0.09
" " " "	22.39	23.56	33.65	......	10.38	10.01	0.007
" " Saltpeter Cave...	22.62	23.13	33.03	......	2.30	18.82	0.07

From this table it is evident that solids from the drip water contain practically twice as much lime as those from the cave earth and much less sulphates and chlorides. Exact calculations for the saturation of bases by alkalies cannot be made without knowing the ratio of soda to potash. An inspection of similar determinations for many Kentucky soils shows for similar situations a ratio of potash to soda of 1 : 4. Assuming this ratio, then, in the case of the drip water, after all the acids are saturated there is a large excess of lime left. This holds true both for the salts given in the above table and for the full analysis as given by Mr. Hess. This lime is held as carbonate and would be deposited as calcite upon evaporation. But in the salts extracted from the cave earths, as before noted, we find that the acids nearly saturate the bases and there is little lime left as carbonate. While the quantities will change as we assume more or less soda in the mixed alkalies, yet the proportions do not vary to any important degree, and in any conceivable case there is a very large excess of calcite in the drip water unaccounted for in the cave earth. In short, the drip in Mammoth Cave carries chiefly carbonates, while the cave earths carry chiefly sulphates. For the drip water to deposit any nitrate it is necessary that it should evaporate practically to dryness and deposit essentially all of its lime and other salts. For every 8 parts of nitric acid, 42 parts of lime will be deposited, and thus the deposit would take the form of stalagmite enclosing the clay or sand, a form of deposit actually found in places but not forming any portion of the cave earth.

The removal of nitrates from guano to cave earth is different. The drip becomes saturated with salts while passing through the guano, deposits only part of its burden in the underlying cave earth, and drains off with the remainder. The deposits thus formed will be composed chiefly of the more soluble instead of the less soluble salts, and no stalagmite will form. This may be made more evident by assuming an ideal case. Take 1 liter of water saturated with calcium nitrate, calcium carbonate, and carbonic acid at 54° F. Keeping the temperature constant, let the water evaporate until only ¾ liter remains. One liter of water at 54° F. will hold in solution approximately 1100 grams of calcium nitrate[1] and (disregarding the influence of the calcium nitrate) only 0.88 gram of calcium carbonate.[2] When reduced to ¾ liter by evaporation it will hold only 825 grams of calcium nitrate and 0.66 gram of calcium carbonate. If the solution be now removed, there remains a precipitate of 275 grams of calcium nitrate and only 0.22 gram of calcium carbonate. This applies to all cases of soluble with slightly soluble salts except where chemical actions intervene, as in the case of phosphates. In one specimen from Dixon's Cave the analysis of the cave earth, recalculated below, shows a very large excess of carbonates. In this case the amount of soluble salts is very minute (0.5655 per cent.), and we probably have the beginning of a stalagmite deposit forming in the nitrates. Over 90 per cent. are bases, with only 5½ per cent. of sulphuric acid. There is no analysis of dropping waters for comparison in this case, however.

SALTS LEACHED FROM CAVE EARTH AND OVERLYING BAT GUANO, DIXON'S CAVE.

	$NaO_2 + {}_2KO$	CaO	SO_3	P_2O_5	Cl	N_2O_5	NH_4
1. Bat guano, Dixon's Cave.....	3.50	31.68	6.35	0.42	—	57.08	0.97
2. Cave earth underlying 1	45.98	40.67	5.48	2.42	—	2.09	3.36

As the overlying bat guano in this case yields up to water salts of which over 57 per cent. are nitric acid, it is difficult to understand how a water carrying the traces of nitrates from the surface of the earth could penetrate this guano to the underlying cave soil without taking along much more nitric acid from the bat guano than the almost infinitesimal quantities it brings from the surface. In this case the soluble part of the deposit is undoubtedly a mixture of the matter in the drip and the matter leached from the bat guano, and there is a bare possibility that a very small quantity of nitrate from the surface may be mixed with the much larger quantity leached from the bat guano above.

---

[1] OSTWALD: Outlines of Theoretical Chemistry, p. 150.

[2] ROSCOE and SCHORLEMMER: Treatise on Chemistry, Vol. II, Pt. I, p. 209.

There are, however, better indicators than the carbonate or sulphate of lime. These are chlorine and the phosphates. The chlorine has not been given in a sufficient number of Mr. Hess' analyses to be available in this discussion, but the data regarding the phosphates are more complete. Inasmuch as phosphates "revert" or become insoluble, the total phosphate, not the soluble, must be considered. Mr. Hess finds only traces of phosphate in the drip or in the soluble extract from the soils of the surface, while the quantity of phosphoric acid in the guano and the niter earth is approximately equal and is very considerable, 2.62 per cent. and 2.10 per cent. respectively. While the approximation to equivalence is doubtless accidental, yet it is undeniable that there is in cave earth much more phosphate in proportion to the niter, alkalies, etc., than the drip water could bring in. An abundance of phosphate is found in soluble form in the bat guano. Mr. Hess regards this excess of phosphate as a concentration in the residual soil, of the calcium phosphate of the limestone on account of its insolubility. But it appears from the figures given by Penrose and others[1] that the percentage of phosphate of lime in limestone and in its residual clay is approximately the same, the larger part of the phosphate going into solution with the carbonate of lime. Penrose selected clay from a hollow in the limestone where it was overlain by 15 feet of similar clay and a chert cap, and compared it with the limestone. He found phosphoric acid in the limestone 3.02 per cent. and in the clay 2.53 per cent. It is not contended that under exceptional circumstances phosphates may not be concentrated as a residuum after solution of limestone, as Safford claims for those of Tennessee, but it is contended that such concentration, if it occur at all, is very unusual, and furthermore that it does not occur in the cave regions of Kentucky and Indiana.

Although no determinations of phosphoric acid in limestone and its residual soil can be found for the immediate vicinity of

---

[1] MERRILL: Rocks, Rock Weathering, and Soils, p. 232.

Mammoth and the other caves considered, yet the above conclusion may be confirmed for the State of Kentucky by the following figures from the analyses of rock and soil made for the Kentucky Geological Survey.[1]

No.	Substance.	P_2O_5, per cent.
570.	Subsoil	0.440
571.	Red underclay	0.425
572.	Limestone	0.221
573.	Limestone	0.196
576.	Subsoil, Bourbon county	0.243
577.	Underclay	0.221
578.	Limestone	0.093
579.	Limestone	0.183
614.	Subsoil	0.316
615.	Limestone	0.311
663.	Virgin soil, Jessamine county	0.239
664.	Virgin soil, Jessamine county	0.666
666.	Limestone	0.567
683.	Subsoil	0.459
684.	Underclay	0.456
685.	Limestone	0.631

In preparing the above table all cultivated soils have been excluded, and it is believed that only examples of virgin soils, subsoils and underlying limestones that are properly comparable have been included. The average of these figures is 0.315 per cent. P_2O_5 for the limestones and 0.365 per cent. P_2O_5 for the soils. The average of twenty-five analyses of subsoils overlying limestone in Kentucky is 0.264 per cent. P_2O_5. Mr. Hess finds 2.62 per cent. P_2O_5 in bat guano and 2.10 per cent. P_2O_5 in cave earth. This is obviously a far greater proportion of phosphate than is found in other residual clays, and as in the drip water he finds only a trace of phosphate with 53.61 milligrams carbonate of lime, the difference can hardly be made up from that source. On the other hand, the bat guano provides an abundant supply, as all the phosphorus used in the metabolic processes of bat life must eventually find its way to the guano. Finally, it

[1] Third Report Geol. Surv. Kentucky.

may be noted that Mr. Hess' claim that nitrates are uniformly distributed in the dry chambers of caves is not substantiated by the analyses of cave earths of Wyandotte Cave made for the Indiana Geological Survey.[1] Besides the analysis of niter earth, there is given one of the magnesian earth which is abundant in the dry portions of Wyandotte Cave. The analysis of this earth shows no nitrates. An interesting variation between the distribution of nitrates and of other nitrogen compounds throws much light upon the problem, and has been investigated by Müntz and Maracano for some Venezuelan caves.[2] "There is thus a gradual change in the character of the nitrogenous combination from the interior to the exterior portions of the cave, as shown in the following analyses:

Constituents	Guano from interior of cave	Earth from entrance	Earth some distance from entrance
Organic nitrogen	11.74 per cent.	2.41 per cent.	0.80 per cent.
Nitrate of lime	0.00 "	3.03 "	10.36 " "

If the transformation of organic nitrogen through ammonia and nitrites to nitrates by the action of bacteria occurs only at the surface, there should be no uniform variation in the proportions of these components in the cave earths, but such a variation as has been found might occur from the mouth of the cave inward if the bacteria are acting in the cave itself. Mr. Hess has doubtless performed a service in pointing out a method by which cavern deposits of nitrates may be formed, and it is not improbable that such deposits may be discovered. Deposits thus formed, however, will have several easily recognized features not found in the cavern earths now known.

HENRY W. NICHOLS.

FIELD COLUMBIAN MUSEUM,
March 2, 1901.

---

[1] Indiana Geol. Surv., 1878, p. 162.

[2] MERRILL: Rocks, Rock Weathering, and Soils, p. 372.

DERIVATION OF THE TERRESTRIAL SPHEROID FROM THE RHOMBIC DODECAHEDRON

Two papers have recently been published which tend to again awaken special interest in the theme of the grand plan of the earth. One is the presidential address of Professor B. K. Emerson on the "Tetrahedral Earth and the Zone of the Intercontinental Seas," delivered before the Geological Society of America; and the other is a lecture before the Royal Geographical Society by Dr. J. W. Gregory, on the "Plan of the Earth and Its Causes."

Both papers are an explanation and discussion of the quaint and suggestive conception of the tetrahedral form of the earth as advanced by William Lothian Green, an English merchant of Honolulu, an original thinker of no mean astuteness, who, in his *Vestiges of the Molten Globe*,[1] presents a hypothesis which can be, by no unbiased student, regarded as lying entirely within the fanciful.

Briefly stated, Green's hypothesis is that on the theory of a cooling globe, a noticeably angular or ridged form would result. As the sphere is the solid which contains the maximum volume under a given surface, so the geometrical form having the minimum volume under the same surface is the tetrahedron. Hence, the contracting globe would tend to assume the tetrahedral shape, as one permitting the greatest reduction of bulk with the least amount of change of surface.

Green takes as his fundamental form the hexatetrahedron with curved faces, as most nearly approaching the sphere. In the development of the hemihedral form of the hexatetrahedron the original faces retained give rise to one set of obtusely pointed pyramids; and the extended portions of the faces a second set of pyramids having more acute apices. The former represent the water areas of the globe and the latter the land areas. There are then three triangles of water with their bases against a land triangle around the south pole, pointed northward and interlocked with three great southward-pointing land triangles, having their bases against the north polar triangle of water. Thus is explained the plan of the earth as indicated by its grandest geographic features.

---

[1] Vestiges of the Molten Globe, Pt. I, London, 1875; Pt. II, Honolulu, 1887.

The idea of a tetrahedral earth did not first originate with Green, though it was doubtless original with him. Neither is the attempt to reduce the earth to a faceted body unusual. From the time of Élie de Beaumont, more or less intense interest has been taken in the subject.

The distinctly tetrahedral conception has been, as Professor Emerson has noted, discussed by a number of writers. Richard Owen,[1] of New Harmony, Indiana, and brother of Dr. David Dale Owen, compared the form of the earth to the crystal of diamond. Besides Green, already mentioned, Michel-Lévy[2] has lately formulated his tetrahedral idea of the earth. Still more recently Gregory[3] has considered the subject much along the same lines as the writer last mentioned.

In comparing Green s tetrahedron with that projected by Michel-Lévy it may be noted that the obtuse pyramids of the former correspond very nearly to the sharp pyramids of the latter.

Now, the main object of the present note is to call attention to the fact that in all of these more recent attempts to reduce the earth to regular geometrical form there is an important suggestion that appears to have escaped notice. This is embodied in a short paper which appeared in the *American Meteorological Journal* for 1888,[4] under the title of the "Probable Derivation of the Terrestrial Spheroid from the Rhombic Dodecahedron." It is by the same Richard Owen who earlier gave expression to many of the facts and fancies connected with the idea of the tetrahedral earth.

[1] Key to the Geology of the Globe, p. 60, 1857.

[2] Bull. Géol. Soc. France, T. XXVI, p. 105, 1898.

[3] Geographical Journal, Vol. XIII, p. 225, 1899.

[4] Am. Meteorological Jour., Vol. V, p. 289, 1888.

The polar axis of the earth is regarded by Owen as extending from the center of one rhombic face to the center of the opposite one. The sharp, four-sided axial angles of the dodecahedron are near the Aleutian Islands, New Zealand, and, on the earth's equator, at Sumatra and Quito; while the remaining two lie in the Alps and south of the Cape of Good Hope. Thus oriented the following propositions are formulated:

1. Centers of rhombs are usually occupied by water or low land;
2. Ridges of rhombs usually give rise to mountains, and river sources; also sometimes to parallel valleys with important rivers;
3. Many of the apices are characterized by vicinity of volcanic groups;
4. Rhombs facing each other have considerable similarity in the distribution of land and water;
5. Daily rotation and annual revolution seem to have determined the configuration of land.

How closely these generalizations accord with facts may be easily tested by reference to any school globe. Why Owen should have oriented the dodecahedron just as he did does not appear. It would seem that in all cases of this kind the starting point which is first selected has much to do with subsequent developments. In Owen's case the depression of the Arctic Ocean offered the schematic rhomb. Then, too, the Mediterranean area required special attention. So important is the last named region that Michel-Lévy, in his plan, was led to make it a point where three polar edges of his tetrahedron should meet.

If there be anything in the idea of a collapsing crust on a shrinking interior, the tendency of the surface toward the assumption of any angular form would find adequate reason in an adjustment which would produce as nearly as possible the least amount of deformation in the lithosphere compared with the amount of change in the bulk of the earth. This geometrical shape is, as already noted, the tetrahedron; but a four-sided figure in which each face would be of the most general form—that is, with six facets—curved after the manner of the diamond.

But while the natural tendency, in a collapsing shell, may be to assume a form affording the least change of the surface, extraneous conditions might impose slight modifications in other directions. The resultant form might then be a closely similar shape, having the same symmetry. As related to the hexatetrahedron, the rhombic dodecahedron is one of these forms. And Owen's scheme may more nearly correspond with observed facts than any plan based upon the strictly tetrahedral conception.

In any case, we should expect to have the great world ridges follow approximately the geometrical edges of whatever form is selected. In the central portions of the faces we should expect to find, on the whole, marked depressions. If these features are to be regarded as essential criteria, then Owen's scheme appears to offer fewer objections than any yet suggested. In these considerations the hydrosphere may be practically neglected.

The rhombic dodecahedron is a schematic form to which the great features of the earth are capable of even more exact adjustment than that proposed by Owen. If the dodecahedron be oriented so that one of its axes coincides with the earth's axis of rotation, the ends of the other two axes may be made to intersect the earth's equator where the latter passes through Sumatra, the west coast of Africa, the west shore-line of South America, and the Phœnix Islands, in the central Pacific Ocean. There will then be grouped around the north pole of the earth four rhombic faces as follows:

1. North American,
2. European,
3. Asian,
4. Bering.

Around the equator are:

5. Northern Pacific,
6. Atlantic,
7. Indian,
8. Eastern Pacific.

About the south pole are arranged:

9. South American,
10. South African,
11. South Indian,
12. South Pacific.

The great Cordilleran ridges of North America, from near the extremity of South America to the Arctic Ocean lie directly on the edges of the dodecahedral form. The line is marked by a remarkable succession of volcanoes both active and only recently extinct. Greenland lies on another of the polar edges of the northern zone of rhombs. Another remarkable world-ridge passes down on rhombic margins from Franz Joseph land, through Novaya Zemlya, the Urals, the Himalayas, Sumatra and the Sunda Islands, Australia to Tasmania. Between the last named place and the south pole is Wilkes Land and Victoria Land, with the active volcano Erebus near the line.

From Sumatra, northeastward extends the most wonderful line of active volcanoes known on the globe — the line bordering the east coast of Asia. From Japan a north polar edge is continued in the long island of Saghalien, certain chains of northeastern Siberia, and farther north in the Arctic Ocean by the Liakov Islands.

Other mountain ridges and groups of active volcanoes characterize most of the other edges of the dodecahedron, frequently in a very notable way.

The only apparently incongruous element in the scheme is Europe. But this comparatively high land has its antipodal representative rhomb in the deepest south Pacific.

However fanciful the speculations of this kind may be regarded, it is certain that mountain ranges are susceptible of systematic arrangement. Moreover, mountain ranges must be considered as having different taxonomic ranks according to their genetic origin.

We know that the smaller folds of the earth's strata are complex, that little ones may ride, as it were, on larger ones, and that these again may rise out of still greater swells. Structural mountains may be thus likened to the waves of a tempestuous sea, and, within each province of the mightiest rolls, may be arranged in harmony with their taxonomic relationships.

The master earth ridges may have one origin, and be arrayed —not in sharply defined geometric figures, perhaps—but in accord with definable laws. Within the grand provinces defined by these greatest features, mountain ranges may be determined by wholly different causes—possibly in out-flowing, curved elevations, something after the manner suggested by Suess for Siberia. Parts of these systems may again be modified by still more local causes—being intensified in some places, softened in others.

In the consideration of mountains, as features of the earth's face susceptible of giving expression to its deepest emotions, we have to recognize fully, before we can hope to understand the riddle of their existence, that all do not possess the same taxonomic values.

CHARLES R. KEYES.

DES MOINES, IOWA.

THE VARIATIONS OF GLACIERS. VI.[1]

THE following is a summary of the Fifth Annual Report of the International Committee on Glaciers :[2]

RECORD OF GLACIERS FOR 1899

Swiss Alps.—As we approach the end of the century the advance of a number of glaciers which began in 1875 has gradually died out. Only one glacier was known to be advancing in 1899; nine were doubtful, and fifty-five were certainly or probably retreating.[3]

Eastern Alps.—During 1899 Drs. Blumcke and Hess published an important paper on the Hintereis glacier containing observations of the movement, melting, and interior temperature of the glacier, and an excellent map.[4] During the time of observation, in the summer, the temperature to a depth of forty meters was found to be practically the melting temperature.

The Vernagt glacier continues to advance; during the last year its velocity at a certain point has increased from 178^{m} per year to 280. Since it has been under observation (1889–1899) its velocity has increased to fifteen times its original value. The ice has thickened and the glacier is advancing.[5]

Of the glaciers observed in the Eastern Alps, fifteen are advancing, thirteen are stationary, and more than twenty-two are retreating.[1]

---

[1] The earlier reports appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383; Vol. VI, pp. 473–476; Vol. VII, pp. 217–225, and Vol. VIII, pp. 154–159.

[2] Archives des Sciences Phys. et Nat., Vol. X, pp. 1–20. Geneva 1900.

[3] Report of PROFESSOR FOREL.

[4] Untersuchungen am Hintereisferner. Wissensch. Ergans. z. Zeit. des D. u. O. Alpenvereins. 1. Bd. 2. Heft.

[5] A very complete account of this glacier was given by PROFESSOR S. FINSTERWALDER in the Wissensch. Erganzunghefte zur Zeits. des D. u. O. A–V. 1. Band, 1. Heft, Graz 1897. This important paper contains a history of the remarkable variations the glacier has suffered, and an excellent discussion of the nature of the movement of the ice and the origin of moraines.

Italian Alps.—Eight glaciers show a retreat and two an advance.[2]

French Alps.—The Société des Touristes du Dauphiné has recently published an important book on the glaciers of Dauphiné.[3] The conclusions are as follows:

As a rule the glaciers of this region have been in retreat during the second half of the nineteenth century, but some became stationary and a few even advanced between 1889 and 1893. Of the glaciers under observation twenty-four are in retreat and two are stationary. One of these, the glacier Blanc, is remarkable; it advanced before 1865, was in retreat from 1865 to 1886, and then began an advance which has continued until 1899; during this period the glaciers nearby were in retreat, though a few of them showed an advance for a short time. Three glaciers at present show a thickening which may result in an advance.

Swedish Alps.—The Mika glacier has been stationary since 1897. Observations have shown a velocity of 18.3^{cm} a day in summer, whereas the mean for the year is 7.6^{cm}.[4]

Norwegian Alps.—A number of glaciers have been under observation and show in general a very slight retreat. The western glaciers of Jotunheim advanced during the summer of 1898. During the last few years a small snowfall and much heat is reported for this region and these glaciers are again in retreat.[5]

Greenland.—Photographs of the small Kiagtut glacier, near Julianehaab, show a retreat of several hundred meters between 1876 and 1899. A small glacier on the island of Disko retreated 46^{m} between 1890 and 1891.[6]

---

[1] Report of PROFESSOR FINSTERWALDER. [2] Report of Mr. OLINTO MARINELLI.

[3] Observations sur les Variations des Glaciers et l'Enneigement dans les Alpes dauphinoises; edited by Professor W. Kilian. Grenoble, 1900.

[4] Report of DR. SVENONIUS.

[5] Report of DR. OYEN. [6] Report of DR. STEENSTRUP.

Canada.—The Victoria glacier, near Lake Louise, Alberta, is retreating though no measures have been made.

Photographs of the Asulkan glacier, British Columbia, show no changes between 1898 and 1899. A small glacier on the southern side of Mt. Sir Donald has become smaller.

The Illecellewaet glacier has been observed with more or less regularity since 1887, during this time it has apparently retreated on the average 15.8^{m} a year. There are indications that it was stationary or advancing before 1887. It retreated 4.9^{m} between 1898 and 1899. In August 1899 the velocity of the ice close to the end was 13.7^{cm} a day; 460^{m} further back and near the middle of the breadth it was 17.2^{cm}. The upper part of the glacier seems to be growing thicker.[1]

Russian Asia.—The report gives the locations of a number of glaciers, many of which show undoubted signs of retreat.[2]

Himalaya.—Mr. Freshfield has induced the government officials to undertake regular observations of some glaciers. He found the glaciers of Kindjinjanga advancing slightly after having suffered an insignificant retreat. In general there are no indications of any important changes among those glaciers in recent years.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1900[3]

The small glaciers in Montana continue to retreat.

A small glacier has been discovered on Mt. Arapahoe in

---

[1] Report of MESSRS. G. and W. S. VAUX, JR. See papers by the same authors: Some observations on the Illecellewaet and Asulkan Glaciers of British Columbia. Proc. Phil. Acad. of Nat. Sci., 1899, pp. 121–124.

Additional Observations on Glaciers of British Columbia. Proc. Phil. Acad. Nat. Sci., 1899, pp. 501–511.

The Glacier of the Illecellewaet. Appalachia, 1900, Vol. IX, pp. 156–165.

ALBRECHT PENCK, translated by D. R. Keys: The Illecellewaet Glacier in the Selkirks. Proc. Canadian Inst. 1900, pp. 57–60.

[2] Report of MR. MOUSCHETOFF.

[3] A synopsis of this report will appear in the Sixth Annual Report of the International Committee. The report on the glaciers of the United States for 1899 was given in this JOURNAL, Vol. VIII, pp. 154–159.

Colorado.[1] The only other glacier known in this state is the Hallett.[2]

The Eliot glacier on Mt. Hood, Washington, is retreating and growing thinner (*H. D. Langille*). This means that the retreat will probably continue for some years and at an increasing rate.

On September 3, 1899, an earthquake shook the Alaskan coast and caused a large quantity of ice to be broken from the ends of tide-water glaciers. Glacier bay was so full of ice during the summer of 1900 that the steamers which usually visit that region were unable to approach Muir glacier nearer than four or five miles, and no satisfactory estimates could be made of the retreat of the glacier.

The Windom glacier, which ends on gravel-deposits in Taku inlet, is reported to have suffered the loss of a large part of its end, due apparently to the washing out of the supporting gravels.

Miles glacier, near the Copper River, Alaska, shows a marked recession since last year (*A. C. Spencer*).

The United States Geological Survey has published a large volume on "Explorations in Alaska in 1898.[3] Several parties were sent to explore various routes from the coast to the interior and, although no especial attention was given to the study of the glaciers, sufficient observations were made to bring out some interesting facts; many glaciers are cursorily described and their locations shown on the maps. The Alaskan glaciers are all of the valley or Piedmont types; Alaska was never under a great ice sheet like the eastern part of North America. The glaciers in the mountainous regions to the north, east, and southeast of Cook's Inlet, many of which are very large, were formerly much more extensive than now, and show evidences of continued retreat. Whereas the glaciers to the west and southwest of Cook's Inlet are small and, though retreating, they were never much larger than at present (*Spurr*, *Mendenhall*, *Eldridge*).

---

[1] The Glacier of Mt. Arapahoe, Colorado, WILLIS T. LEE: This JOURNAL, Vol. VIII, pp. 647–654.

[2] F. H. CHAPIN: Appalachia, Vol. V. p. 1; and Mountaineering in Colorado, p. 97.

[3] Twentieth Ann. Rept. U. S. Geol. Surv., Part VII. See also ABERCROMBIE: The Copper River Exploring Exped. Washington, 1899.

Professor I. C. Russell has published an account of the former and present glaciation in northern Washington.[1] A synopsis of the existing glaciers in this region was given in an earlier report of this series.[2]

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
March 15, 1901.

---

[1] I. C. RUSSELL: A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington. Twentieth Ann. Rept. U. S. Geol. Surv., Part II.

[2] This JOURNAL, Vol. IV, pp. 222–224.

PRODROMITES, A NEW AMMONITE GENUS FROM THE LOWER CARBONIFEROUS

CONTENTS

Occurrence of Paleozoic Ammonites.
 Genus: *Prodromites* Smith and Weller, *gen. nov.*
  Prodromites gorbyi (Miller).
  Prodromites praematurus Smith and Weller, *sp. nov.*
 Conclusion.

Occurrence of Paleozoic Ammonites.—Until twenty-five years ago it was thought that the ammonites were confined entirely to the Mesozoic, and that the Paleozoic representatives of the Ammonitoid group were all goniatites. This was in keeping with the theory that ammonites all belonged to a single stock or phylum. But the discovery in the Salt Range Permian of several genera of different stocks that could not, by any stretching of the name, be called goniatites, upset this idea. For a long time after this the Permian ammonite fauna of India was looked upon as exceptional until the recognition of the Permian age of the ammonite fauna of the Artinsk beds of Russia. This was followed shortly by the discovery of similar forms in strata of the same age in Sicily and in Texas. It was then universally recognized that these forms were not exceptional, and might be looked for wherever the uppermost Paleozoic was found in its marine facies. But even as late as 1891 we find the Permian ammonite species of Texas described as Mesozoic types occurring in Paleozoic beds, and in all text-books even today the Permian epoch is given as the period of transition from goniatites into ammonites.

Steinmann and von Sutner[1] were the first to attempt to divide the ammonites into various phyla, derived from separate stocks of goniatites, and while their classification is not always in agreement with the most rational arrangement, it is very suggestive, and has caused much fruitful discussion. The main points for which they contended have been accepted, and now it is generally admitted that ammonite genera may be much more closely related to goniatites than they are to contemporaneous or even antecedent ammonites. Karpinsky's[1] masterly researches in the phylogeny of the Prolecanitidæ contributed largely to this result, and prepared the way for Haug's[2] exhaustive study of the relations of the various phyla of goniatites.

---

[1] STEINMANN: Elemente der Palaeontologie, 1890.

When it is once admitted that there are several distinct stocks of different degrees of specialization and developing in different directions, there is no longer any sound reason for the commonly accepted opinion that they all made the transition at the same time; indeed, it is extremely illogical to expect that this would be the case. In spite of this, it will cause surprise, especially among those that cling to time-honored criteria, when it is announced that not only are characteristic ammonites found below the Permian, but even at the very base of the Carboniferous system, and in such an advanced stage of development that the transition from goniatite to ammonite must have taken place already in the Devonian. The occurrence of these forms is authentic, and not sporadic, for they were found in the same horizon, and in the same faunal association in three widely separated localities in America. It may be that they were prematurely specialized forms, like *Clymenia*, that developed suddenly from the main, unspecialized stock, and as suddenly became extinguished; but the existence of similar and evidently closely related forms in the Trias presupposes continuance of the stock. In reality, our knowledge of the various families of Paleozoic animals is as yet only fragmentary, and lack of record is no very strong argument against the occurrence of any group. We must remember that the greater part of the Paleozoic deposits are not now open to our inspection, and that whole faunal provinces and regions are now obliterated, either washed away entirely, or covered by the sea, or concealed by later deposits. The first records in the rocks or in text-books do not, by any means, agree with the first appearance of any group in geologic history. This is clearly seen when one notes the constant pushing back of the records of the first appearance of types, that has taken place in the past ten years. Our ideas of the specialization of organic life in Cambrian and even pre-Cambrian time have had to undergo radical changes as the discoveries of new faunas have followed fast upon each other.

---

[1] Die Ammoneen der Artinsk-Stufe. Mém. Acad. Impér. Sci. St. Petersburg, seventh series, Tome XXXVII, No. 2, 1889.

[2] Études sur les Goniatites. Mém Soc. Géol. France, Paléontol., Tome VII, No. 18, 1898.

Genus, **Prodromites**, *gen. nov.*, Smith and Weller.

Type, *P.* (*Goniatites*) *gorbyi* Miller, 1891, Advance Sheets Seventeenth An. Rep. Geol. Survey of Indiana, p. 90, Plate XV, Fig. 1; and Seventeenth An. Rep. Geol. Survey of Indiana, 1892, p. 700, Plate XV, Fig. 1.

The type species was originally described as a goniatite, but a most liberal interpretation of that group could not include this form, which was assigned to that division simply because of its occurrence in Carboniferous rocks.

The genus *Prodromites*[1] is characterized by its laterally compressed, discordal, involute, deeply-embracing whorls, narrow umbilicus, high, hollow abdominal keel, and complex, ceratitic septa. Where the keel is broken off, as is usually the case, the abdomen is narrow, slightly flattened, and angular. The surface, so far as known, is smooth, and destitute of ribs, constrictions, or other ornamentation. The septation is the most distinctive feature of this genus, on account of the large number of serrated lobes, and an extensive auxiliary series of lobes and saddles. The ventral lobe is rather long and undivided, the saddles all rounded and entire, the first four or five lateral lobes are serrated, and in addition to these there is a series of several pointed and more or less irregular auxiliary lobes.

The only Paleozoic form to which *Prodromites* may be likened is *Beloceras*, which it resembles only in its compressed involute form and the multiplication of the elements of the septa. The resemblance is not great, but the agreement is fundamental, and these two genera may safely be placed in the same family or phylum. A much greater resemblance and probably kinship connects this form with *Hedenstroemia* Waagen, of the Lower Trias of the oriental region. The best known species of that genus is *H. mojsisovicsi* Diener, Pal. Indica, *Cephalopoda of the Lower Trias*, page 63, Plate XX,

---

[1] The etymology of the word is from the Greek of scout or forerunner.

Figs. 1 *a–c*. In *Hedenstroemia*, as defined by Waagen,[1] the ventral lobe is divided, the external saddle divided by adventitious lobes; the first four lateral lobes are serrated, and there is a series of about six pointed auxiliary lobes. The form is flattened, involute with narrow and angular abdomen. No keel is known, and the shell is smooth. In *Prodromites* the ventral lobe is undivided and the external saddle is entire and rounded; but in the serration of the first four or five lateral lobes and in the auxiliary series it is almost identical with *Hedenstroemia*, as also in the form, with the exception of the keel, which may not have been preserved on the few specimens known. There can be no doubt that these two genera belong to the same family, and even subfamily, in spite of the long time that intervened between the Kinderhook formation of the Lower Carboniferous and the Lower Trias. *Hedenstroemia*, according to Waagen,[1] belongs to the Pinacoceratidæ, subfamily Hedenstroeminæ, which also contains *Clypites* Waagen, and *Carnites* Mojsisovics, of the Lower Trias. The family Pinacoceratidæ in the broader sense, as defined by Waagen (*op cit.*, p. 139), contain all forms with compressed involute whorls, many lateral lobes and saddles, and an auxiliary series of lobes outside of the umbilicus. In this family belong the following subfamilies: (1) Medlicottinæ, (2) Beloceratinæ, (3) Beneckeinæ, (4) Hedenstroeminae; all of which have representatives in American Paleozoic or Triassic strata.

It is not likely that *Prodromites* is a descendant of *Beloceras*, since the septation is quite different in the two genera; and unless *Hedenstroemia* should be found to have a keel, it is not likely that it has descended from *Prodromites*. *Beloceras* is commonly placed under the Prolecanitidae, although it antedates any typical species of *Prolecanites*. On the other hand, *Medlicottia*, which is closely related to *Prodromites*, seems certainly to have been a descendant of the typical Prolecanitidæ. No solution of these questions is possible until the ontogeny of several of these genera is known, which is prevented at present by a scarcity of specimens. Until other evidence is forthcoming, *Prodromites* is placed in the family Pinacoceratidæ, subfamily Hedenstroeminæ.

This genus is not founded solely on Miller's figure, which is not accurate, nor even on his type specimen, but also on three other specimens of this species, and one of another species, bringing out certain characters that did not show on Miller's type.

The writers have had at their disposal for study four specimens of *Prodromites gorbyi* Miller, and one of *P. praematurus* S. and W., all of which, except one, belong to the paleontological collection of the Walker

[1] Pal. Indica. Salt Range Fossils. Fossils from the Ceratite Formation, p. 140.

[1] Pal. Indica. Salt Range Fossils, Vol. II. Fossils from the Ceratite Formation, p. 140.

Museum at the University of Chicago, to the authorities of which the writers' thanks are due for the use of the specimens. The first specimen,[1] No. 6208, is Miller's type of *Goniatites gorbyi*, and came from the Chouteau limestone at Pin Hook Bridge, Pettis county, Missouri. A second specimen, No. 6474, was secured from Professor G. C. Broadhead. It is better preserved than the type, but in the same sort of limestone, and while it is merely labeled "Chouteau limestone, Pettis county, Missouri," it probably came from the same locality as the type. A third specimen, No. 6222, is recorded merely from the Kinderhook beds of Burlington, Iowa. The material in which it is preserved is a buff or yellowish, rather finely crystalline limestone, the position of which in the Kinderhook section at Burlington is probably near the top, between the oolitic limestone and the buff magnesian bed, which lies immediately below the Burlington limestone of Osage age, or in the basal portion of the oolite bed. This horizon may then be correlated with the Chouteau limestone of central Missouri.

A fourth specimen of *P. gorbyi* was studied by the writers in the collection of Fred. Braun, of Brooklyn, N. Y. It came from the Kinderhook goniatite bed of Rockford, Indiana, associated with *Prolecanites lyoni* Meek and Worthen, *Aganides rotatorius* de Koninck, *Muensteroceras oweni* Hall, *M. parallelum* Hall, and thus is certainly in the zone of *Aganides rotatorius* of the Tournaisian horizon of the Lower Carboniferous.

A fifth specimen of the genus, No. 6223, belongs to a new species (*P. praematurus* Smith and Weller). It came from the Kinderhook goniatite beds of Rockford, Indiana.

Geologic horizon.—Since this genus occurs in the same horizon, in rocks of different lithologic character, and in three localities separated by hundreds of miles, it may be considered as characteristic of the Chouteau limestone horizon of the Lower Carboniferous, equivalent to the lower part of the Tournaisian horizon of the European Dinantian formation. At present *Prodromites* is unknown outside of America, and but two species are known, in the Mississippi valley region, from the three localities mentioned.

Prodromites gorbyi Miller. Plate VI, Figs. 1. Plate VII, Fig. 9. Plate VIII, Figs. 1, 2.

1891 *Goniatites gorbyi* Miller, Adv. Sheets, Seventeenth Rep. Geol. Survey of Indiana, p. 90. Plate XV, Fig. 1.

1892 *Goniatites gorbyi* Miller, Seventeenth Rep. Geol. Survey of Indiana, p. 700. Plate XV, Fig. 1.

Neither the description nor the figure given by Miller of this type is accurate, the drawings of the septa being entirely too generalized.

---

[1] The numbers refer to the Walker Museum collection.

The form is laterally compressed, involute, discoidal, with very narrow umbilicus. The abdomen is narrow, and surmounted by a high narrow hollow keel, which however is usually not preserved. Where the keel is broken away the abdomen is narrow, less than a millimeter wide, with angular edges. The sides are smooth, devoid of constrictions, ribs, or other ornamentation, so far as could be determined from the casts.

The septa are complex, ceratitic, with many lobes and saddles. The ventral lobe is long and undivided. The external saddle is rounded and shorter than the laterals. The first lateral lobe is serrated, four-pointed; the second, four-pointed; the third, the three-pointed; the fourth, irregularly three-pointed; the fifth irregularly bifid. With the sixth lateral lobe begins the auxiliary series of goniatitic lobes, which are of irregular size, and eight in number, growing smaller towards the umbilicus. These characters could not be made out distinctly on Miller's type specimen No. 6208, but the details were clearly seen on specimen No. 6474, from the same locality. The differences between the two specimens, at a casual glance, might seem to be specific, but closer study shows them to be due to difference of preservation, and to different sizes at which the septa are seen. The type specimen shows the keel only at a few places on the periphery, and so indistinctly that Miller overlooked it, while No. 6474 shows the keel, 3½ millimeters high, entirely around the periphery. On both specimens the body chamber is incomplete and occupied a little over a quarter of the last revolution. It is not known what was the shape of the aperture, how long the body chamber was, when the keel began, nor what the internal lobes were like, since none of the specimens available sufficed to settle these questions.

A smaller specimen, No. 6222, from the Kinderhook beds of Burlington, Ia., showed much simpler septa, and the narrow angular abdomen with the keel broken off. It is undoubtedly in the beginning of the mature stage of growth, and was of value in showing the shape of the cross-section, since both sides were free from the matrix, while in all other specimens one side was fixed to the matrix.

At present there are known only four specimens of *Prodromites gorbyi*.

1. Miller's type, from the Chouteau limestone at Pin Hook Bridge, Pettis county, Missouri. No. 6208, Paleontological Collection, Walker Museum, University of Chicago. This is the type of the genus *Prodromites* Smith and Weller.

DIMENSIONS

Diameter	114^{mm}
Height of last whorl	64
Height of last whorl from the preceding	35
Width of last whorl	..
Involution	29
Width of umbilicus	4

2. Specimen obtained from Professor G. C. Broadhead, Chouteau limestone, Pettis county, Missouri, probably from the same locality as the last. No. 6474, Paleontological Collection, Walker Museum, University of Chicago.

DIMENSIONS

Diameter	117$^{\text{mm}}$
Height of last whorl	68
Height of last whorl from the preceding	38
Width of last whorl	..
Involution	30
Width of umbilicus	5 ?

3. Specimen from the Kinderhook limestone of Burlington, Ia., near the top of the Kinderhook Series as exposed at that locality. No. 6222, Paleontological Collection, Walker Museum, University of Chicago.

DIMENSIONS

Diameter	75$^{\text{mm}}$
Height of last whorl	42
Height of last whorl from the preceding	25
Width of last whorl	10
Involution	17
Width of umbilicus about	4

4. Specimen from the Kinderhook goniatite limestone of Rockford, Ind.; in the paleontological collection of Fred. Braun, of Brooklyn, N. Y., where it was examined by the writers. Its dimensions are about the same as of the two specimens from Missouri.

Prodromites praematurus sp. nov., Smith and Weller. Plate VIII, Figs. 3, 4.

Type is specimen, No. 6223, Paleontological Collection, Walker Museum, University of Chicago. Form laterally compressed, discoidal, involute, deeply embracing, with narrow umbilicus, narrow slightly flattened abdomen surmounted by a hollow keel three millimeters high. Whorl indented by the preceding whorl to a little over one third of its height. Surface smooth, so far as known.

The septa are complex, ceratitic, with rounded entire saddles, serrated lateral lobes, and a series of auxiliaries above the umbilicus. The ventral lobe is narrow, and undivided; the first lateral is longer, and three pointed; the second lateral, four-pointed; the third lateral, bifid; the fourth lateral, bifid, but more deeply so than the third; then begins a series of auxiliary lobes, undivided and pointed, seven in number.

The only species with which *Prodromites praematurus* might be compared is *P. gorbyi*, from the same horizon ; but in *P. praematurus* the abdomen is slightly broader, the shell rather thicker, the septa rather more complex, and the umbilicus slightly wider than on *P. gorbyi* at the same diameter. In the figures and the descriptions of the septa a difference between the two species may easily be seen.

DIMENSIONS

Diameter - - - - - - - - - -	62^{mm}
Height of last whorl - - - - - - - -	34
Height of last whorl from the preceding - - -	21
Width of last whorl - - - - - - - -	9.5
Involution - - - - - - - - - - -	13
Width of umbilicus - - - - - - - -	6.5

This specimen was septate throughout, so the length of the body chamber could not be ascertained.

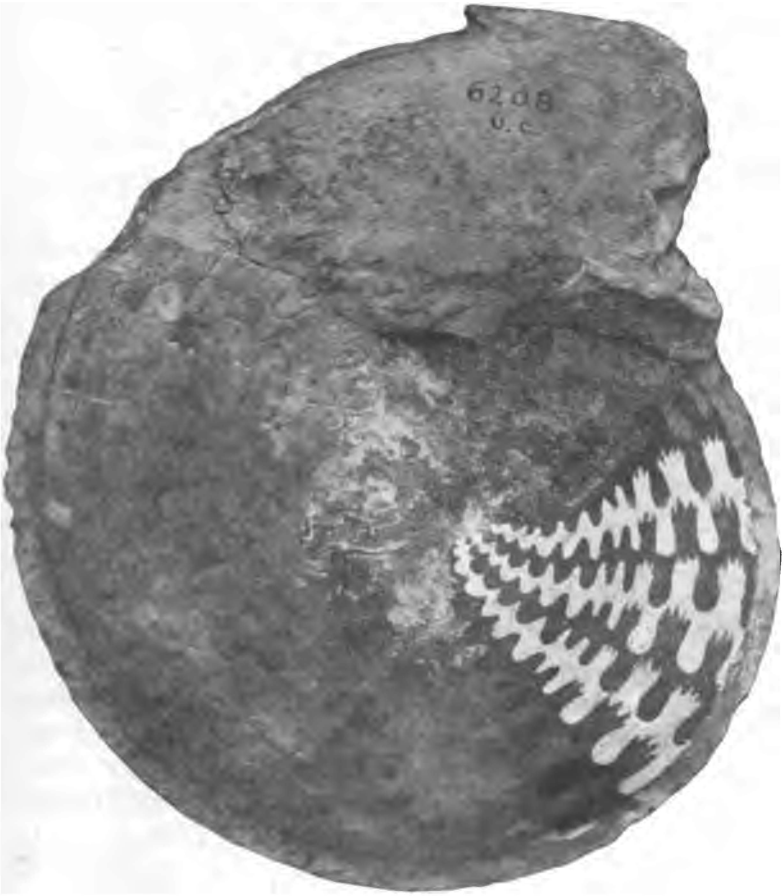
Only a single specimen is known, No. 6223, of the Paleontological Collection, University of Chicago, from the Kinderhook goniatite limestone of Rockford, Indiana.

CONCLUSION

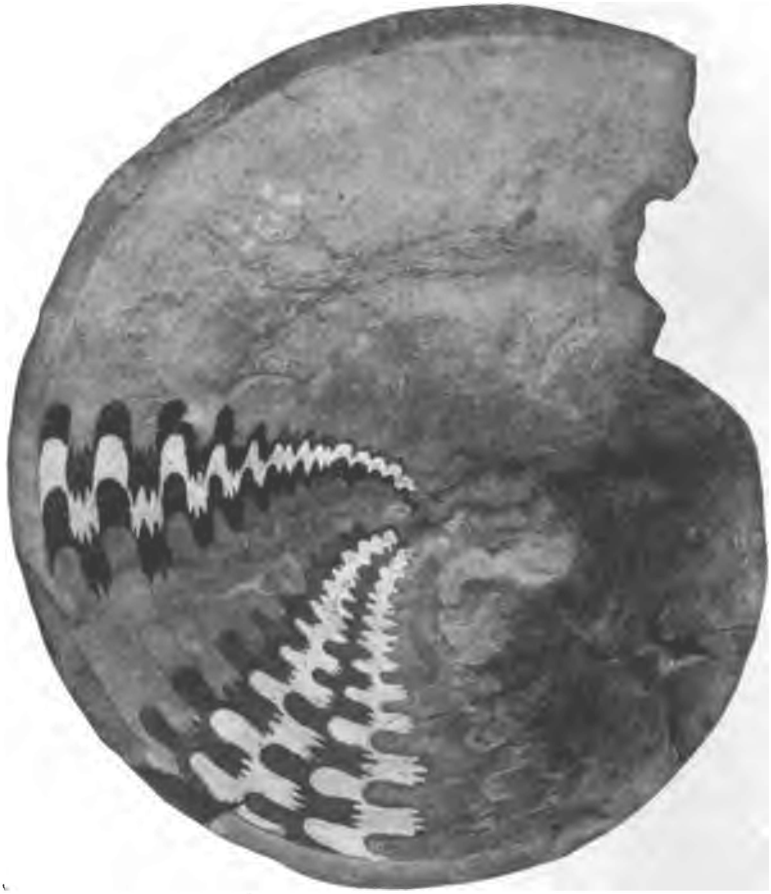
In *Prodromites* we have the oldest known ammonite and the most complex ammonoid yet described from strata older than the Permian, occurring only a short distance above the base of the Lower Carboniferous. In all probability the ancestors of this genus had already become ammonites before the close of the Devonian, but we do not know where to look for them. The Kinderhook ammonoid fauna is exotic in America, and seems to be exotic wherever it is known. But in the faunal region from which this migration came we may expect to find a highly specialized fauna of which those forms that made their way into Europe and America in Tournaisian time are but a fragment. We have, as yet, no clue as to where this region was, but the vast unexplored Paleozoic stretches of Asia lead us to hope for much new information when that continent shall be thoroughly investigated.

The occurrence of such forms as *Prodromites*, without local ancestors serve only to emphasize our ignorance of the ancient zoology of regions outside our own, and should stimulate research in geographic distribution of fossil faunas.

Jour. Geol., Vol. IX, No. 3 Plate VI

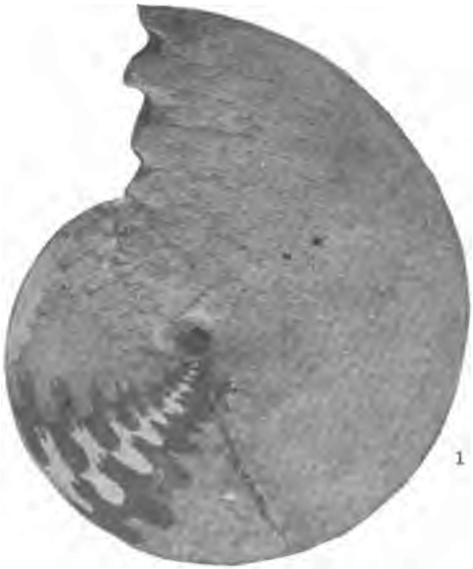


1

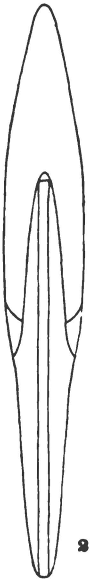


1

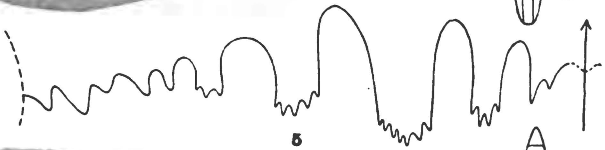
Jour. Geol., Vol. IX, No. 3 Plate VIII



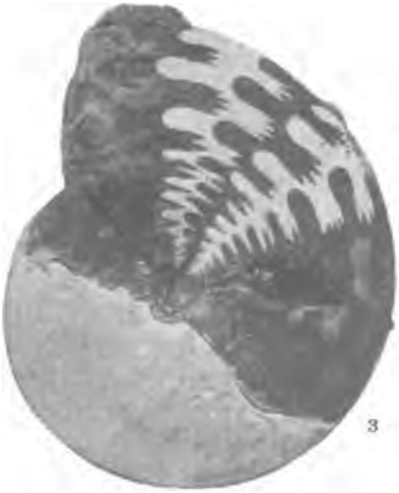
1



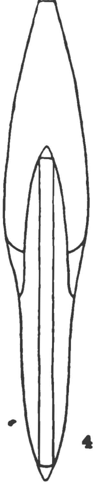
2



5



3



4

EXPLANATION OF PLATES

(All figures are natural size)

PLATE VI

FIG. 1. *Prodromites gorbyi* (Miller). No. 6208 Pal. Coll. Walker Museum. Miller's type specimen from the Chouteau Limestone, Pin Hook Bridge, Pettis county, Missouri.

PLATE VII

FIG. 1. *Prodromites gorbyi* (Miller). No. 6474 Pal. Coll. Walker Museum. From the Chouteau Limestone, Pettis county, Missouri.

PLATE VIII

FIG. 1. *Prodromites gorbyi* (Miller). No. 6222 Pal. Coll. Walker Museum. From the Kinderhook beds, Burlington, Iowa.

FIG. 2. Front view of the same.

FIG. 3. *Prodromites praematurus* sp. nov. Smith and Weller. No. 6223 Pal. Coll. Walker Museum. From the Kinderhook Goniatite bed, Rockford, Indiana.

FIG. 4. Front view of the same.

FIG. 5. Septa of *Hedenstroemia mojsisovicsi* Diener. After C. Diener, Pal. Indica, series 25, Vol. II, Part II, Plate XX, Fig. 1*c*.

JAMES PERRIN SMITH,
STUART WELLER.

EDITORIAL

In the death of Dr. George M. Dawson, director of the geological survey of Canada, American geology has lost one of its ablest representatives. Not only as an individual worker, but as an administrator, he displayed unusual capacity and gave promise of still larger achievements in the future. That so promising a career should be cut short so suddenly at the climax of its productiveness is sad indeed, and the loss is keenly felt by the scientific world. When the vastness of the area whose investigation was being conducted under his direction, and its important relations to many of the great outstanding problems of geology, are recalled, the misfortune of the interruption of his successful administration and of his personal labors is most fully realized.

Dr. Dawson enjoyed unusual privileges of education and early association, which, combined with his native capacity for absorption and assimilation, gave him an unusual breadth of learning and catholicity of interest, and these qualities were called into active and manifold expression in the exposition of the broad and complex phenomena of the great Canadian field. He was gifted with notable literary abilities, and these, combined with a charming personality, gave grace and geniality to all his presentations. We hope to present a critical sketch of his work in a future number. T. C. C.

It is a hopeful sign for the future terminology of our science that manifestations of dissatisfaction with its current nomenclature are just now taking on active and declared forms. During the last few weeks conferences have been held in different quarters at which the improvement of existing usage has been the special subject of discussion. It is not proposed to dwell upon these here, though it is hoped that the JOURNAL may have something further to say upon the subject at an early date, but merely to say a word on the special issue raised by the articles of Messrs. Cumings and Siebenthal in this number, which appear together by mutual concurrence. These articles bring up the question how far the law of priority, rigorously interpreted, shall determine all subsequent usage, and how far other considerations may properly weigh against it. It appears that in this case the term "Bedford" was used by Owen as early as 1862 in describing the well-known Indiana formation; but that it was not then formally proposed as the scientific name of the formation. In 1870 Dr. Newberry proposed the name "Bedford shale" for an entirely different formation, found at Bedford, *Ohio*. Since then the term "Bedford stone" has become familiar throughout the country as the commercial designation of the rock so extensively shipped from the Indiana town, and this use will quite certainly continue in spite of any technical usage which geologists may propose. Two practical questions therefore arise:

1. Does the familiar use of a term in an official report as the designation of a given formation in any sense or to any degree preoccupy the term so that it may not be used advisedly as the formal name of any other formation, particularly a formation in the same geological province? Specifically, did the use of the term "Bedford rock" by Owen in any degree preoccupy the term "Bedford" so that it was improperly selected as the formal name of a formation in Ohio?

2. Does the growth of such a name into very common usage, together with the certainty that this common usage must prevail in spite of any technical practice that may be adopted by geologists, constitute a sufficient reason for not applying the term technically to any other formation in the same province?

There is also the more general question, whether our science should be burdened for all time to come by infelicities in the choice of a name made by a busy worker who may have been able to give but a passing thought to the selection of a name, and who may have been unaware at the time of the infelicities likely to arise out of it. In short, shall the rule of priority, rigidly and technically interpreted, be observed for all time, however infelicitous it may prove to be?

These are questions upon which at present there are differences of opinion. It seems altogether wise to keep them in a state of agitation until geological opinion shall formulate itself on mature and permanent grounds. We are passing from the initial stages of our science, in which the discovery of formations, like the discovery of animal and plant species, has predominated, into a more mature stage, in which these elements will lose their importance through the recognition of gradations, of evolutions, and of those broader and profounder relationships which will constitute the really important phases of the subject to future students. It is fitting, therefore, that we should consider whether the verbal lumber that may have had importance in the initial stages shall be transmitted, without modification or adaptive evolution, to the whole future of the science. To the writer it seems important to the future of the science that its language should be developed along the lines of greatest serviceability and esthetic merit. It seems, furthermore, quite possible to give all due honor to the initial discoverer without injury to the language of the science; indeed, it would seem in some instances that the initial discoverer would be honored by the rejection or the modification of his unfortunate nomenclature. Is it not within the limits of permissible practice to set aside an unfortunate name and to substitute a new one, and at the same time leave the credit of primal identification to the original author? It does not seem that priority of discovery and of description is inseparably connected with priority of nomenclature.

It is not the purpose of this note, nor the policy of the JOURNAL, to urge at once a decision in this special case or in similar cases, but rather to urge that the question of nomenclature be kept open and be the subject of thoughtful study until all of the considerations that should enter into the formation of the language of the science have been brought forth into distinct recognition and have been duly pondered. After sufficient time has been allowed for a deliberate consideration on these broader lines, and a consensus of opinion has been matured as a result, general rules may perhaps be reached. Meantime a measure of freedom may be allowed to individual judgment. T. C. C.

THE writer has read the proof of the article "On the use of the term Bedford limestone," by Mr. C. E. Siebenthal, which appears in this number of the *Journal of Geology*. Mr. Siebenthal's argument in reference to "the prior claims of Indiana to Bedford as a formation name" rests entirely upon the occurrence of the term "Bedford rock" in Owen's report on Lawrence county, published in 1862, which we have shown was *not* used in the sense of a formation name and was not described. The sentence in which "Bedford rock" occurs is as follows: "The Bedford rock has long been celebrated for its excellent qualities as a building stone, and is extensively shipped; additional localities are being opened, and only require the liberality of railroad directors to furnish switches and other facilities for still more extended sales."[1] The name was used in the same sense as the names of hundreds of other towns have been applied to the rock quarried in their vicinity but without any intention to have them serve as the names of geologic units. If they were recognized as formation names the number of synonyms for the consideration of the stratigraphical geologist would be enormously increased.

Bedford shale was published as the name of a geological division by Dr. Newberry in 1870[2] and fully described by him in 1873.[3] Following the single occurrence of "Bedford rock" in Owen's report the next citation of "Bedford stone" by Mr. Siebenthal is from the Indiana report for 1873, published in 1874,[4] in which Professor John Collett described the "Geology of Lawrence county" and under the geological division of the St. Louis limestone, which was composed of beds No. 24–17 inclusive, he stated that "bed No. 22, is the quarry bed which furnishes in unlimited supply the famous 'Bedford stone' so favorably known. . . . . This stone is composed almost wholly of minute fossils cemented with shell and coal dust. It varies in color from gray to a creamy white, and may be quarried in blocks or columns the entire thickness (12 feet) of the stratum."[1] Under the geological section of the county bed No. 22 is described as "White quarry limestone" from 4 to 12 feet in thickness.[2] It is evident on reading the report that Professor Collett did not use the term "Bedford stone" as the name of a geologic unit. Furthermore, this report and the following citations by Mr. Siebenthal have no bearing upon the question of the priority of Bedford as a formation name because they are all antedated by Dr. Newberry's precise delimination and description of the Bedford Shales of northern Ohio.

---

[1] Rept. Geol. Reconnoissance Indiana, 1862, p. 137.

[2] Rept. Geol. Surv. Ohio, Pt. I, Rept. Progress in, 1869; p. 21.

[3] Rept. Geol. Surv. Ohio, Vol. I, Pt. I, pp. 188, 189.

[4] Fifth Ann. Rept. Geol. Surv. Indiana made during the year 1873-4, p. 276.

Mr. Siebenthal's second point that "to the trade, *Bedford stone* it will be to the end of the chapter" does not appear to the writer to have any particular bearing upon the question. He does not believe when a scientific classification and one used in trade fail to agree that it is necessary for the former to withdraw in favor of the commercial one. A still more striking example of the difference between the trade and geological name is that of the "North or Hudson River bluestone," the trade name used for the sandstone so largely employed for flagging and house trimmings in New York and other eastern cities. The trade name was in use before the rocks of eastern New York were classified; but the geologists did not use it for the name of a geological division, although the name Hudson River group was used for an older formation than the one in which the quarries were located. The belt of country containing this "bluestone" extends for nearly one hundred miles north and south on the western side of the Hudson River and the early quarries were in rocks of the Hamilton formation. As these were partially exhausted new quarries were opened to the westward in rocks of the Sherburne formation, and later farther west in the Catskill Mountain region in rocks of the Catskill formation. At the present time the greater part of the "bluestone" is obtained from the Sherburne and Catskill formations; but to the trade it is all generally known and sold as the "Hudson River bluestone."

---

[1] Fifth Ann. Rept. Geol. Surv. Indiana made during the year 1873–4, p. 276.

[2] Loc. cit., p. 265.

The name Bedford shale was given by Dr. Newberry to the geologic unit which is well exposed at Bedford village, southeast of Cleveland. The formation varies in thickness from fifty to one hundred feet; is sharply defined lithologically with its base resting on top of the black Ohio shale while its top is marked by the base of the Berea grit. In distribution it extends from eastern Ohio across the northern part of the state to Huron county, and thence south across the state to the Ohio River and into Kentucky. At a few localities in northern Ohio, especially near Cleveland, the shale includes from fifteen to twenty feet of valuable sandstone which is used considerably in that city for flagging and building stone. The Bedford shale of Ohio is as thick a formation as the Bedford limestone of Indiana; lithologically it is more sharply limited; it has, apparently, as great areal distribution; as the name of a definite geologic division it has appeared in geological literature for a longer time and to a much greater extent; but it does not contain as valuable economic deposits of building stone.

CHARLES S. PROSSER.

May 2, 1901.

Reviews.

The Norwegian North Polar Expedition, 1893–1896. Scientific Results. Vol. II. Edited by Fridtjof Nansen. Longmans, Green & Co., London, New York, 1901. VI. H. Geelmuyden, *Astronomical Observations*, pp. 1–136, with two charts. VII. Aksel S. Steen, *Terrestrial Magnetism*, pp. 1–196, with 17 plates. VIII. O. E. Schiøtz, *Results of the Pendulum Observations and some Remarks on the Constitution of the Earth's Crust*, pp. 1–90.

The astronomical observations have their chief geological value in the accurate determination of localities. While they are thus fundamental and indispensable, they afford in themselves little matter of note for the reviewer. The observations were chiefly made by Captain Sigurd Scott-Hansen. They are abundant and bear evidence of having been taken with accuracy, and they thus contribute a valuable precision to all other observations dependent upon locality.

The second part of the volume is devoted to the discussion of the magnetic observations of the expedition, which were also made by Scott-Hansen. Concerning the value of these observations, Mr. Steen remarks: "It is of especial importance to obtain determinations of the magnetic elements from the polar regions, because the observations have naturally hitherto been rather scarce from these deserted wastes, containing large tracts where the foot of man has never yet trod, and whose physical conditions place all kinds of difficulties in the way of delicate scientific investigations. They are also important because the action of the earth's magnetic forces in these very regions, judging from the observations that have been obtained, presents peculiarities to which there is no parallel in the temperate and torrid zones." The general results are summarized in tables giving the declination, horizontal intensity, and inclination at the numerous localities of observation.

The third part, which relates to pendulum observations, has, without doubt, the greatest interest for geologists. These pendulum observations are the first systematic determinations of the force of gravity over the great ocean depths. "The observations show that the gravity may be regarded as normal over the polar basin; and as it is not probable that this is a peculiarity of the Polar Sea, we are led to the assumption that the force of gravity is normal all over the great oceans. The increased attraction observed on oceanic islands must therefore only be due to the local attraction of the heaped-up masses at the bottom of the ocean that form the islands" (p. 63). This determination of the normal character of the force of gravity over the ocean depths, if its theoretical extension to all the ocean basins be justified, must be regarded as a contribution of the first order. The determination in the polar basin was made possible by the relative fixity of the vessel in the ice. The tremors which more or less constantly affect the polar ice sheets may perhaps have slightly influenced the results but probably in no serious way. Regarding the theoretical extension, it is however to be noted that these polar observations were nowhere made at a great distance from the edge of the continental plateau, and that the extent of the depression is undetermined, and that, furthermore, the depth of the sea is somewhat less than the average depth of the ocean. The polar basin is probably not, at most, much greater in extent than the Mediterranean basin, and may be much less. It would seem, therefore, that some reserve may be prudently exercised in accepting the assumption that the observations in the Polar Sea determine the force of gravity over the great ocean depths in general. In view of the importance of determining this beyond question, it may be suggested that attempts be made to make pendulum observations in the calm belts of the tropics. This suggestion is made on the assumption that the sea might there be found sufficiently calm to permit observations of approximate accuracy.

The discussion of the crust of the earth, which follows that of the pendulum observations, is less satisfactory than it might have been, owing to the limitation of the theoretical assumptions to a single line of hypothesis. Apparently the results might be appreciably different, if different hypotheses of the internal constitution of the earth had been assumed. The discussion proceeds upon the conception that all the differences in the density of the solid portion of the earth are confined to its superficial portion. This is doubtless in accord with present majority views based on deductions derived from prevalent theories as to the origin and early state of the earth, but it is none the less unsatisfactory, because it involves some assumptions which are apparently incompatible with the necessary deductions of physics, and which must probably be abandoned, whatever may happen to speculative views of the earth's genesis. For example, it is assumed that there is now an inner nucleus of uniform density forming a perfect spheroid, and that the outer surface that is now the ocean bottom was originally nearly or quite on a level with that on the continents, and that the present oceanic depressions are the result of progressive sinking due to cooling. Lord Kelvin, however, is authority for the statement that "there seems to be no possibility that our present day continents could have risen to their present heights, or that the surface of the solid in its other parts could have sunk down to their present ocean depths, during the twenty or twenty-five million years which may have passed since the *consistentior status* began or during any time however long." (On the Age of the Earth as an Abode Fitted for Life, p. 706.) And this conclusion is supported by independent considerations. The thickness of the earth's crust is taken by Professor Schiøtz to be 0.02 of the earth's radius, or about eighty miles. If as supposed it rests upon a spheroidal nucleus of uniform density and perfect form, the difference in thickness in different parts amounts to fully 10 per cent. of its own thickness when reckoned only between plateaus and antiplateaus, neglecting mountain heights. A *difference* of contraction to the amount of 10 per cent. is quite incredible, as is also any remote approach to this amount. The *average* difference between the thickness of the crust beneath the continental plateaus and that beneath the ocean bottoms is, under the assumption made by the author, more than 3 per cent. of the whole crustal thickness, and this is more than can reasonably be attributed to any *difference* in contraction due to cooling. In view of these and other considerations, it would have been more satisfactory if the discussion had been extended to the postulates of other hypotheses of the inner constitution of the earth: among them, the assumption that an uneven distribution of density reaches to profound depths.

Nevertheless, it is a great gain to the study of the earth's dynamics that a treatment of the problem from the point of view of pendulum data extended to the ocean surface has been ventured, even though it be confined to a single line of hypothetical postulates.

T. C. C.

Meteorological Observations of the Second Wellman Expedition. By EVELYN B. BALDWIN, Observer, Weather Bureau. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900. Part VII. Washington, 1901.

This report embraces in full detail the meteorological observations made by Mr. Baldwin in connection with the second Wellman expedition. The observations relate especially to the meteorological conditions at and in the vicinity of Franz Josef Land, from June 1898, to August 1899, embracing observations made on shipboard between Tromso, Norway, and Franz Josef Land, those made at Harmsworth House and at Fort McKinley, on Franz Josef Land, and those made in the field, partly on Franz Josef Land and partly on the ocean north of there. To atmospheric geologists, the summations relative to the prevalent direction of the wind and cloud movements will perhaps possess the greatest interest. These show that the prevalent atmospheric movement was emphatically from the northward. The observations upon the upper clouds, which perhaps best express the general movement, may be grouped as follows:

N. W.	19 per cent.	
N.	20 per cent.	
N. E.	19 per cent.	
E.	10 per cent.	
		68 per cent.
S. E.	4 per cent.	
S.	2 per cent.	
S. W.	2 per cent.	
W.	6 per cent.	
		14 per cent.
Calms		18 per cent.

Fifty-eight per cent. are from N. W., N., and N. E., while only 24 per cent. are from the remaining five points.

Separating these into those that have an easterly and westerly component, the observations take this form:

North		20 per cent.
With easterly component:		
N. E.	19 per cent.	
E.	10 per cent.	
S. E.	4 per cent.	
		33 per cent.

With westerly component:		
N. W.	19 per cent.	
W.	6 per cent.	
S. W.	2 per cent.	
		27 per cent.
South		2 per cent.
Calm		18 per cent.

From these data it will be seen that there is but very slight preponderance of the easterly component over the westerly, and that the aggregate direction is almost due north.

Analyzing in a similar way the observations on the lower clouds, we have:

N. W.	13 per cent.	
N.	20 per cent.	
N. E.	25 per cent.	
E.	5 per cent.	
		63 per cent.
S. E.	7 per cent.	
S.	6 per cent.	
S. W.	15 per cent.	
W.	6 per cent.	
		34 per cent.
Calm		4 per cent.

Summing up with reference to eastward and westward components, we have the following:

North		20 per cent.
With easterly component:		
N. E.	25 per cent.	
E.	5 per cent.	
S. E.	7 per cent.	
		37 per cent.
With westerly component:		
N. W.	13 per cent.	
W.	6 per cent.	
S. W.	15 per cent.	
		34 per cent.
South		6 per cent.
Calm		4 per cent.

The result is practically the same as before.

The emphatic preponderance of northerly winds, and the slightness of the average deviation to the east over that to the west, are points of interest and should receive the consideration of the advocates of a "circumpolar whirl." Of course, conclusions are not to be drawn from these limited data (and data taken in an expedition of this kind are necessarily limited), but they are in consonance with many other data that invite a reconsideration of prevalent theories of atmospheric circulation.

When the conditions under which these observations were made are considered, their number and their nature must be regarded as a high tribute to the scientific devotion of the observer.

T. C. C.

The Oriskany Fauna of Becraft Mountain, Columbia County, N. Y. By J. M. Clark, Ph.D., Mem. N. Y. St. Mus., No. 3, Vol. III.

Becraft Mountain is an outlier composed chiefly of strata of early Devonian age, resting conformably upon the upturned slates of the Hudson River formation. A preliminary paper on the fauna of the Oriskany formation at this locality was published in 1899 by Professor C. E. Beecher, being accompanied by a list of the species present identified by the author of the present report. It was shown at that time that the fauna was a peculiar one, consisting of an intermingling of Helderbergian and Oriskany forms. The present report is a detailed description of the fauna accompanied by good illustrations of all the species.

This discussion of the Becraft Mountain Oriskany fauna by Dr. Clark, brings clearly into view a very different conception of the faunas of Oriskany age in eastern North America from that which has become known through Volume III of the New York Paleontology. At Becraft's Mountain, and in strata extending southward through New York and into New Jersey, a calcarious facies of Oriskany sedimentation occurs, which contains a very different assembly of organisms from that of the original Oriskany sandstone, and which is considered by Dr. Clark as being the normal fauna of the period. In this connection Dr. Clark writes: "In the earlier presentation of this fauna it was regarded as of Lower Oriskany horizon, on account of the presence of many Helderbergian species, but we believe it will be more correctly construed as the representation of the proper and normal Oriskany fauna, the true fauna of this time unit inclosed in the sediments of its proper habitat."

The character of the Oriskany sandstone deposits in New York from Schoharie county westward are shown to be "a series of arenaceous lenses connected by thin sheets of quartzitic sandstone." In regard to the fauna of these lenses, it is said: "The great brachiopods, *Spirifer arenosus*, *Rensselaeria ovoides*, *Hipparionyx proximus*, and *Meristella lata*, with *Tentaculites elongatus*, which are the species generally present in these lenses, could not have had their habitat on such a deposit and in a sea whose depth favored such deposition. We shall not be wrong in regarding these accumulations of remains in the true Oriskany sandstone as agglomerations, swept out of their facies and away from the more calcareous, deeper water deposits of the time. To regard them as species of the sandy facies of Oriskany time would, I believe, be altogether erroneous. They appertain truly to the calcarious facies and the normal fauna of the Oriskany time."

In the summation of the fauna, ninety-four clearly defined species are recognized, of which "thirty-eight represent expressions of species which began their existence in Helderbergian time; on the other hand but eighteen species of the fauna continue their existence or appear to be represented by closely allied forms beyond the close of the Oriskany sedimentation." Twenty-nine species of the fauna are recognized in the arenaceous Oriskany beds.

The evidence afforded by this fauna as the true Siluro-Devonian boundary line is of much importance. No one disputes the Devonian age of the Oriskany formation, and this fauna demonstrates that there is no natural faunal break in passing from the Helderbergian to the Oriskany, as there should be if the Helderbergian was excluded from the Devonian.

The closing pages of the report are devoted to somewhat minute discussion of the Silurian and Devonian characteristics of the Helderbergian fauna, both the positive and the negative elements being considered, and to a discussion of the stratigraphic argument based upon the relationships of the Maulius limestone.

S. W.

Recent Publications

—**Abbe, Cleveland, Jr.** The Physiographic Features of Maryland. [Reprinted from the Bulletin of the American Bureau of Geography, Vol. I, 1900.]

—**Adams, Frank D.** Memoir of Sir J. William Dawson. [From Bulletin of the Geological Society of America, Vol. XI, 1899.]

On the Probable Occurrence of a Large Area of Nepheline-Bearing Rocks on the Northeast Coast of Lake Superior. [Reprinted from the Journal of Geology, Vol. VIII, No. 4, 1900.] The University of Chicago Press.

—**Adams, F. Dawson**, and **John T. Nicholson.** An Experimental Investigation into the Flow of Marble. Philosophical Transactions of the Royal Society of London, Series A, Vol. CXCV, pp. 363–401. Plates 22–25. Dulau & Co., 37 Soho Square, W., London, 1901.

An Experimental Investigation into the Flow of Marble (Abstract.) From the Proceedings of the Royal Society, Vol. LXVII. Read June 21, 1900.

—**Ami, Henry M.** On the Geology of the Principal Cities in Eastern Canada. [From the Transactions of the Royal Society of Canada, Second Series, 1900–1, Vol. VI, section 4, Geological and Biological Sciences.]

On a New or Hitherto Unrecognized Geological Formation in the Devonian System of Canada. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 5, for January 1901.]

Synopsis of the Geology of Canada (being a Summary of the principal terms employed in Canadian geologic nomenclature). [From the Transactions of the Royal Society of Canada, Second Series, 1900–1, Vol. VI, section 4, Geological and Biological Sciences.] Issued March 25, 1901.

—Australasian Institute of Mining Engineers, Proceedings of. Annual Meeting, Melbourne, January 1901.

—British Association for the Advancement of Science, Report of the Seventieth Meeting, held at Bradford in September 1900. John Murray, London, 1900.

—**Burr, Henry T.** The Structural Relations of the Amygdaloidal Melaphyr in Brookline, Newton, and Brighton, Mass. Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXVIII. Geological Series, Vol. V, No. 2. With 2 plates. Cambridge, Mass., 1901.

—Canadian Pleistocene Flora and Fauna. Report of the Committee, consisting of Sir J. W. Dawson (chairman), Professor D. P. Penhallow, Dr. H. Ami, Mr. G. W. Lamplugh, and Professor A. P. Coleman (secretary), reappointed to continue the investigation of the Canadian Pleistocene Flora and Fauna. I. On the Pleistocene near Toronto, by Professor A. P. Coleman. II. On the Pleistocene Flora of the Don Valley, by Professor D. P. Penhallow.

—CUSHING, H. P. Preliminary Report on the Geology of Franklin County, Part III. [Reprinted from the Eighteenth Report of the State Geologist.] Albany, 1900.

—DALY, REGINALD A. The Physiography of Acadia. Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXVIII. Geological Series, Vol. V, No. 3. With 11 plates. Cambridge, March 1901.

—DAWSON, GEORGE M. Geological Record of the Rocky Mountain Region in Canada. Bulletin of the Geological Society of America, Vol. XII, pp. 57–92, February 25, 1901. (Address by the president, George M. Dawson. Read before the society December 29, 1900.) Rochester, 1901.

—DORSEY, GEORGE A. An Aboriginal Quartzite Quarry in Eastern Wyoming. Field Columbian Museum, Publication 51. Anthropological Series, Vol. II, No. 4. Chicago, December 1900.

—EKHOLM, DR. NILS, Stockholm. On the Variations of the Climate of the Geological and Historical Past and their Causes. [From the Quarterly Journal of the Royal Meteorological Society, Vol. XXVII, No. 117. January 1901.]

—FARRINGTON, OLIVER CUMMINGS. Observations on Indiana Caves. Field Columbian Museum, Publication 53. Geological Series, Vol. I, No. 8. Chicago, February 1900.

—Field Columbian Museum, Publication 52. Annual Report of the Director to the Board of Trustees for the year 1899–1900. Report Series, Vol. I, No. 6. Chicago, October 1900.

—GEIKIE, SIR ARCHIBALD. The Founders of Geology. The George Huntington Williams Memorial Lectures on the Principles of Geology, Vol. I. Baltimore, The Johns Hopkins Press, 1901.

—Geological Society of America, Bulletin of the. Index to Vols. I to X, by Joseph Stanley-Brown. Rochester, December 1900.

—HALE, GEORGE E. The New Star in *Perseus.* Bulletin No. 16. The Yerkes Observatory of The University of Chicago. The University of Chicago Press, 1901.

—HALLOCK, CHARLES. One of Canada's Explorers. [Reprinted from Forest and Stream.] Washington, 1901.

—Hilgard, Eugene W. A Historical Outline of the Geological and Agricultural Survey of the State of Mississippi. [Reprinted from Publications of the Mississippi Historical Society, Vol. III.]

—Hollick, Arthur. Fossil Plants from Louisiana. Contributions from the Geological Department of Columbia University, Vol. IX, No. 67.

—Holst, Nils Olof. Bidrag till Kännedomen om Östersjöns och Bottniska Vikens Postglaciala Geologi. [Sveriges Geologiska Undersökning, Ser. C, No. 180] Kungl. Boktryckeriet. P. A. Norsted & Söner, Stockholm, 1899.

—Kansas, The University Geological Survey of. Vol. VI. Paleontology, Part II, Carboniferous and Cretaceous. By Samuel W. Williston, Paleontologist; Joshua W. Beede and Alban Stewart, Assistant Paleontologists; Sydney Prentice, Artist.

—Kemp, J. F. The Re-Calculation of the Chemical Analyses of Rocks, Contributions from the Geological Department of Columbia University, Vol. IX, No. 71. [Reprinted from the School of Mines Quarterly, No. 1, Vol. XXII.]

—Kolderup, Carl Fred. Die Labradorfelse des Westlichen. I. Das Laboradorfelsgebiet bei Ekersund und Soggendal. [From the American Geologist, Vol. XXIV, August 1899.]

—Leverett, Frank. Old Channels of the Mississippi in Southeastern Iowa. [From the Annals of Iowa for April 1901, Vol. V, pp. 38–51.]

—McGee, W J The Old Yuma Trail. [Reprinted from the National Geographic Magazine, March-April 1901.] Washington, 1901.

—Merrill, George P. Curator Divison of Physical and Chemical Geology, and Head Curator Department of Geology, U. S. National Museum. Guide to the Study of the Collections in the Section of Applied Geology. The Non-metallic Minerals. [From the Report of the U. S. National Museum for 1899, pp. 155–483, with 30 plates.] Washington, 1901.

—North Dakota, Report of the Geological Survey of, for 1900. First Biennial Report. E. J. Babcock, State Geologist. Grand Forks, N. D., 1901.

—Penhallow, D. P. Notes on the North American Species of Dadoxylon, with special reference to type material in the collections of the Peter Redpath Museum, McGill University. From the Transactions of the Royal Society of Canada, Second Series, 1900–1. Vol. VI, section 4, Geological and Biological Sciences.

—Petersen, Johannes, Hamberg Hamm. Ueber die Krystallinen Geschiebe der Insel Sylt. [Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie, Geologie und Palaentologie. Jahrg. 1901, Bd. I. S. 99–110.] Stuttgart, E. Schweitzerbart'sche Verlagshandlung (E. Nägele), 1901.

—Porto Rico, Report on the Census of 1899. Taken under the direction of the War Department. Washington: Government Printing Office, 1900.

—PROSSER, CHARLES S. Names for the Formation of the Ohio Coal-measures. [From the American Journal of Science, Vol. XI, March 1901.]

Sections of the Formations along the Northern End of the Helderberg Plateau. [From the Eighteenth Annual Report of the State Geologist.] Albany, N. Y., 1901.

—RICHTER, E. Les Variations Périodiques des Glaciers. Cinquiéme Rapport, 1899. Commission Internationale des Glaciers. [Extrait des Archives des Sciences physiques et naturelles, t. X, 1900.] Genéve, Librairie Georg & C^ie^, 1900.

—RITCHEY, G. W. Celestial Photography with the 40-inch Visual Telescope of the Yerkes Observatory. [Reprinted from the Astrophysical Journal, Vol. XII, No. 5, December 1900.] The University of Chicago Press, Chicago.]

—ROGERS, A. W. and E. H. L. SCHWARZ. The Orange River Ground Moraine. [Reprinted from the Transactions of the Philosophical Society of South Africa, Vol. XI; Part II, September 1900.]

—SMITH, JAMES PERRIN. Principles of Paleontologic Correlation. [Reprinted from the JOURNAL OF GEOLOGY, Vol. VIII, No. 8, 1900.] The University of Chicago Press, Chicago.

The Biogenetic Law from the Standpoint of Paleontology. [Reprinted from the JOURNAL OF GEOLOGY, Vol. VIII, No. 5, 1900.] The University of Chicago Press, Chicago.

The Larval Coil of Baculites. [Reprinted from The American Naturalist, Vol. XXXV, No. 409, January 1901.] Ginn & Co., The Atheneum Press, Boston, 1901.

—Smithsonian Institution, Annual Report of, for the year ending June 30, 1897. Report of the U. S. National Museum. Part II. A Memorial of George Brown Goode. Washington, 1901.

—STEVENSON, JOHN J. Edward Orton. [Reprinted from the JOURNAL OF GEOLOGY, Vol. VIII, No. 3, April-May 1900.] The University of Chicago Press.

The section at Schoharie, N. Y. [Reprinted from Annals New York Academy of Sciences, Vol. XIII, No. 3, pp. 361–380, January 12, 1901.] Lancaster, Pa., The New Era Printing Co., 1901.

—STUART-MENTEATH, P. W. Progres de la Geologie des Pyrénées. Sur les Pyrénées de la Feuille de Mauléon. [Extraits du Compte-Rendu Sommaire des Séances de la Société Géologique de France No. 16, séance du 19 Novembre 1900, pp. 132 et 134.] Papers read by the President, M. A. de Lapparent, at meeting of November 19, 1900.

—WAHNSCHAFFE, FELIX. Die Ursachen der Oberflächengestaltung des Norddeutschen Flachlandes. Mit 9 Beilangen und 33 Textillustrationen. J. Engelhorn, Stuttgart, 1901.

—Washington Academy of Sciences, and Affiliated Societies, Directory of the. 1901.

—Washington Academy of Sciences, Proceedings of:

Mammals collected by Dr. W. L. Abbott on the Natuna Islands. By Gerritt S. Miller, Jr. Vol. III, pp. 111–138, March 26, 1901.

Papers from the Harriman Alaska Expedition. XX. The Nemerteans. By Wesley R. Coe, Yale University. Vol. III, pp. 1–110, Pls. 1–13. March 26, 1901.

Results of the Branner-Agassiz Expedition to Brazil. V. Mollusks from the vicinity of Pernambuco. By William Healey Dall. New Birds of the Families Tanagridæ and Icteridæ. By Robert Ridgway. Vol. III, pp. 139–155, April 15, 1901.

—WATSON, THOMAS L. Weathering of Granitic Rocks of Georgia. Bulletin of the Geological Society of America. Vol. XII, pp. 93–108, Pls. 6–11. Rochester, February 1901.

—Wisconsin Academy of Sciences, Arts, and Letters. Transactions of the Vol. XIII, Part I, 1900. With 28 plates. Edited by the Secretary, Madison, 1901.

—WILLIS, BAILEY. Paleozoic Appalachia, or The History of Maryland during Paleozoic Time. Maryland Geological Survey, Special Publication. Vol. IV, Part I. The Johns Hopkins Press, Baltimore, November, 1900.

—WINCHELL, ALEXANDER N. Mineralogical and Petrographic Study of the Gabbroid Rocks of Minnesota; more particularly of the Plagioclasytes. [Reprinted from the American Geologist, Vol. XXVI, 1900, Minneapolis, Minn.] With a map and 13 plates.

—WINCHELL, N. H. Glacial Lakes of Minnesota. Bulletin of the Geological Society of America. Vol. XII, pp. 109–128, 12 plates. Rochester, February 1901.

THE
JOURNAL OF GEOLOGY

MAY–JUNE, 1901

GLACIAL AND INTERGLACIAL BEDS NEAR TORONTO

An article on the present subject was published in 1895 in the JOURNAL OF GEOLOGY;[1] but the five years since that time have added so much to the completeness of our knowledge of this important Pleistocene area as to justify a fresh account of the region. At the Toronto meeting of the British Association in 1897 the series of interglacial beds for which Professor Chamberlin had suggested the name "Toronto Formation" aroused so much interest that a committee was appointed for its investigation and grants were made at this and the two following meetings to cover the expense of excavations to solve some problems in connection with the beds. The final report of the committee, prepared by its secretary, the present writer, with a separate report on Pleistocene plants in Canada by Professor Penhallow, was made at Bradford in 1900, summing up the facts and giving lists of the interglacial fauna and flora, thus providing the materials for a more complete discussion of the events recorded in the "drift" of the region than has been attempted before.

The interglacial beds of Scarboro' near Toronto were first studied more than 20 years ago by the well-known English paleontologist, Dr. George Jennings Hinde,[1] but his excellent work attracted little attention and the importance of the facts brought to light seems to have been overlooked by Pleistocene geologists. In 1894 the Don interglacial beds were described by the present writer,[2] who has since then given careful study to the numerous and excellent sections presented by Scarboro' Heights, the ravines of the Don, and many excavations carried on in and about the city of Toronto. A large number of fossils have been collected by Mr. J. Townsend and the writer, and Professor Penhallow has determined the plant remains, Dr. Dall and his assistants the shells, and Dr. Scudder the insects. These gentlemen have shown the greatest skill and patience in working up what was often very difficult material, and much of the value of the results of the investigation is due to them, particularly in determining

---

[1] JOUR. GEOL., Vol. III, No. 6, pp. 622, 645.

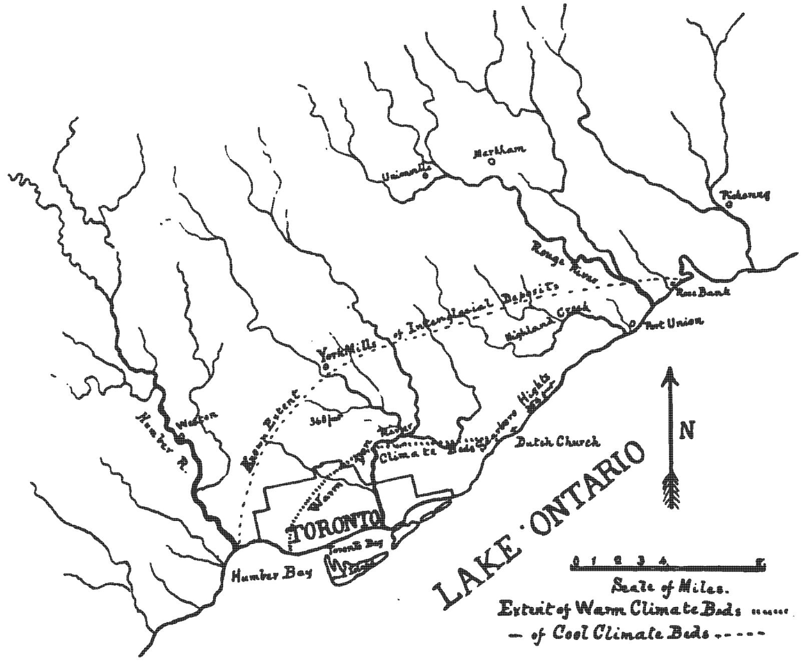


FIG. 1.

---

[1] Canadian Journal, 1878, p. 388 *et seq.* [2] Am. Geol., Vol. XIII, 1894, pp. 85–95.

the important changes of climate indicated. In the following paper an attempt will be made to give a connected history of the events which have occurred in the Ontario basin during the time represented by the Toronto Formation and the sheets of till below and above it, generally held to belong respectively to the Iowan and Wisconsin ice advances.

RETREAT OF THE IOWAN ICE SHEET

The retreat of the Iowan ice was probably accompanied by one or more lakes similar to those whose raised beaches, formed during the retreat of the last ice sheet, are so well marked around the present great lakes. Though no remnants of Iowan beaches are known to exist, there is strong faunal evidence of at least one glacially dammed Iowan lake. When the region was ice covered, all aquatic life must have been destroyed, so that any species occurring in interglacial beds must have migrated into the region from river systems beyond the reach of the ice. The unios which are so striking a feature of the lower beds of the Toronto Formation are Mississippi forms. As there is no more proof of direct connection between the Ontario basin and tributaries of the Mississippi during interglacial times than now, we may suppose that these shellfish entered the basin in a round-about way by means of an interglacial upper lake, draining at first past Chicago into the Mississippi, but afterwards finding an outlet by the Laurentian river into the Ontario valley and thence into the gulf of St. Lawrence.

After the Iowan glacier had retreated so far that lakes dammed by it had been drained, the St. Lawrence system of waters no doubt returned to much the same channels as before the advance of the ice, since there is no evidence that any great thickness of drift had been left to block the way. The lowest till at Toronto is generally thin, running from a foot or more near the bend of the Don at the paper mill to 8 or 9 feet at the Gerrard street bridge. At one point in the west end of the city, however, 35 to 40 feet of till occur, but a well-defined "bowlder pavement," with all the stones at the same level and striated on their upper surfaces, is found 4 or 5 feet above Lake Ontario, and perhaps indicates that the upper 30 feet are of later age than the Iowan. Farther west along the shore of the lake the till sheet is not more than 10 or 15 feet thick. So far as known, this layer of till is nowhere thick enough to have modified greatly the shape of the surface, which may now be roughly sketched.

The highest point of the Hudson River shale near Toronto is at Weston, 7 miles northwest of the city, where it reaches about 200 feet above Lake Ontario. In the Don valley the shale runs from a little below lake level near the mouth of the river to 30 feet above it 2 or 3 miles to the north; but 5 miles east of the Don a well sunk at the foot of Scarboro' Heights failed to reach the rock at 41 feet below the lake, and beyond this bedrock is not found for a long distance, first appearing at Pickering, 15 miles to the east. This implies a width of about 25 miles for the mouth of the valley occupied by the preglacial (and also interglacial) Laurentian river whose old channel from Georgian Bay to Scarboro' has been indicated by Dr. Spencer.[1] The valley narrowed somewhat rapidly, however, toward the northwest, for on the upper reaches of the River Rouge between Unionville and Markham numerous angular slabs of Hudson River rock, evidently not far from their source, are found more than 300 feet above Ontario. The distance from this point to Weston is 16 miles in a southwesterly direction, and between the two points, the ravines of the Don and wells which have been sunk prove that a channel of considerable depth existed.

[1] Duration of Niagara Falls and History of the Great Lakes, pp. 18 and 19.

Dr. Spencer's idea of a present channel 474 feet deep, running from Scarboro' Heights across Ontario to the deep water near the south shore seems founded on an erroneous sounding as marked on Bayfield's chart. A series of soundings carried out by the present writer in 1898 across the supposed deep channel showed no such interruption in the gentle southward slope of the bottom, the depth at about the position of the 474 feet sounding on the chart being 175 feet. Probably the 4 is in mistake for 1, and the true sounding was 174 feet. The old channel across Lake Ontario was filled in completely, so far as one can ascertain, by stratified clay and till in later times and so has long ago disappeared. The fact that Scarboro' Heights, rising 375 feet above the lake, have been piled up since then may be considered sufficient proof of this.

We may suppose then that the great preglacial valley, though coated with a sheet of bowlder clay by the Iowan ice, had probably much the same form and dimensions at the end of that ice invasion as before. If there was an interglacial episode similar to the postglacial lake Iroquois no certain remains of its beach deposits are known, and the level of the water when the laying down of the Toronto Formation began was not greater than that of Lake Ontario and may have been considerably beneath it; for the lowest unio beds lie more than 40 feet beneath the present lake at Scarboro'.

Before the formation of similar beds at higher levels considerable erosion took place, as at the bend of the Don where these deposits occupy an old river channel cut through the Iowan till into the Hudson River shale to the depth of at least 16 feet, as shown by a cutting of the Don, at this point 19 feet above Ontario. The bowlder clay has been cut through to the shale in the western part of Toronto also, as shown in a well bored for purposes of exploration, the bottom of the interglacial deposits being 17 feet above Lake Ontario. It seems clear that rivers had been at work for some time before the unio beds were formed.

WARM CLIMATE BEDS OF THE DON VALLEY

The earliest beds of the Toronto Formation were deposited on the eroded surface of the Iowan till or on the shales which had been laid bare beneath it by river action; and they were formed probably in the shallow waters of a lake, though some features suggest the action of currents. At the bend of the Don, coarse, little rounded shingle of the harder layers of the underlying Hudson River rocks makes the lowest bed visible above the present river, and suggests the action of a current rather than of waves. Thick sheets of vegetable matter, greatly decayed twigs, leaves, reeds, etc., with trunks and branches of trees are interbedded with the shingle, however, showing that the current could not have been swift. Possibly these beds were formed just at the mouth of a small river like the present Don, where it entered a lake standing 20 or 30 feet higher than Ontario. If this is correct there had already been a damming back of the interglacial waters to a higher level than has been reached yet in postglacial times. This damming could not have been by ice, for the climate was at least as mild as at present, since the tree trunks referred to include wood of the red cedar, an elm, the pawpaw and three species of oak; and among the shellfish there are two not reported from Canadian waters at the present day, though found in the Mississippi, Quadrula (unio) pyramidata and Anodonta grandis.[1]

As the beds at Taylor's brickyard, which have been described in former papers, have been traced as far east as the bend of the Don at the edge of the interglacial valley just referred to and also as a thin lower layer across these deposits, we may include the whole in one section, commencing with the bend of the Don as a basal series and running up through the series at the brickyard as far as the cold-climate stratified clays.

SECTION AT TAYLOR'S BRICKYARD

		Feet
8.	Yellow or brown sand with some reddish clay (no fossils)	3–60½
7.	Blue peaty clay with some gray sand (unios, wood, caribou horn)	4½–57½
6.	Yellow to brown sand with thin layers of purplish clay (shells)	14–53
5.	Fine gray and yellow sand (unios and other shells)	3–39
4.	Blue stratified clay and sand (unios with other shells and logs of wood), above 2½ feet of bowlder clay resting on Hudson River shale	2–36

SECTION AT BEND OF DON

3.	Brown clay with sandy layers (unios, campeloma, etc.)	5–34
2.	Blue clay with sandy layers (unios, anodons, wood)	6–29
1.	Coarse shingle with clay and peaty layers (shells and logs)	4–23
	River Don above Lake Ontario	19–19

From the combined section given above it will be seen that the warm climate beds of the Don commencing 19 feet above Lake Ontario have a total thickness of 41½ feet. It should be added however that no fossils have been obtained from the uppermost three feet of brown sand. The lower section differs slightly in fauna from the upper one, containing numerous anodons and campelomas, which are almost absent from the beds at the brickyard; but the unios and trees are alike.

---

[1] Notes on Can. Unionidae, J. F. WHITEAVES, Can. Rec. Science, 1895, No. 5, p. 250; and No. 6, p. 365.

In previous papers the warm climate beds have been represented as ending just beneath the peaty blue clay (No. 7) which was considered to belong to the cool climate beds, chiefly because it contained peaty layers and had yielded a shed horn of caribou. Recently, however, the peat has been examined and found to contain no mica scales and very few mosses or spruce needles, which are very characteristic of the peaty layers belonging to clays of the cool climate. Instead of this the brown layers consist mainly of fragments of deciduous leaves. The recent finding of unios at the top of the blue clay strengthens the opinion that it and the brown sand above should be included with the warm climate beds. The lowest point at which the unio clays and sands have been found is 41 feet below Lake Ontario at the foot of Scarboro' Heights, giving a vertical range of more than 100 feet for the whole series of warm climate beds The following species have been obtained in the Don beds:

FAUNA OF WARM CLIMATE BEDS, DON VALLEY

Vertebrata: possibly mammoth or mastodon and bison, and an undetermined fish.

Arthropoda: several undetermined beetles and cyprids.

Mollusca:

Unio undulatus	still living in Lake Ontario.
" rectus	
" luteolus	
" gibbosus	
" phaseolus	still living in Lake Erie, but not reported from Lake Ontario.
" pustulosus	
" trigonus	
" coccineus	
" occidens	not known in the St. Lawrence system of waters, but living farther south.
" solidus	
" clavus	
" pyramidata	

Anodonta grandis, not reported from Canada.

Sphaerium rhomboideum
" striatinum
" sulcatum
" solidulum
" similis (?)
Pisidium Adamsi
" compressum
" novaboracense (?)
Pleurocera subulare
" elevatum
" Lewisi (?)
Goniobasis depygis
" Haldemani
Limnaea decidiosa
" elodes

Planorbis parvus
" bicarinatus
Amnicola limosa
" porata
" sagana
Physa heterostropha
" ancillaria
Succinea avara
Bythinella obtusa
Somatogyrus isogonus
Valvata sincera
" tricarinata
Campeloma decisa
Bifidaria armata (land snail)

In all there are thirty-nine undoubted species of mollusks, and three more probably, included in the fauna. Of these eight or ten have not been reported from Lake Ontario, but occur farther south.

FLORA OF WARM CLIMATE BEDS, DON VALLEY

Acer pleistocenicum
" spicatum
Asimina triloba
Carya alba
Chamaecyparis sphaeroidea
Crataegus punctata
Cyperaceae sp.
Eriocaulon sp.
Fraxinus quadrangulata
" sambucifolia
" americana
Festuca ovina
Hypnum sp.
Juniperus virginiana
Larix americana
Maclura aurantiaca
Picea nigra
" sp.
Pinus strobus

Platanus occidentalis
Populus balsamifera
" grandidentata
Prunus sp.
Quercus obtusiloba
" alba (?)
" rubra
" tinctoria
" oblongifolia
" macrocarpa
" acuminata
Robinia pseudacacia
Salix sp.
Taxus canadensis
Thuya occidentalis
Tilia americana
Ulmus americana
" racemosa
Vaccinium uliginosum

Professor Penhallow, from whose report to the British Association in 1900 this list is taken, states that "within this area no less than thirty-eight species have been recovered, and they point conclusively to the existence of climatic conditions differing materially from those which now prevail, and of a character more nearly allied to those of the middle United States of today." "Only one species appears to have disappeared in Pleistocene time. Acer pleistocenicum, which was abundant in the region of the Don, bears no well defined resemblance to existing species."

The plant remains consist chiefly of wood and leaves, the former usually much flattened from the pressure of the later ice sheet, but otherwise often well preserved, the red cedar, for instance, showing its color and being still quite tough, although some of the wood, probably decayed before being waterlogged and included in the clay, is in a worse condition. Parts of the wood are almost of the nature of brown coal breaking across easily and showing a coaly luster on the broken surfaces. It may be worthy of mention that some large bits of porous charcoal, as if from the burning of a log, were found cemented with limonite in the sand (No. 6) just under the blue clay. The leaves are preserved generally in the thinner beds of clay and are rarely obtained whole.

The sands of the Don beds vary greatly in fineness and color, and are more or less cross bedded and mixed with gravel, as if deposited under wave action; while the coarse shingle at the base of the section near the bend of the Don looks like the work of a river. The upper part of the warm climate beds of the Don, consisting of stratified clay (No. 7) and sand (No. 8) appears to have been formed under distinctly lacustrine conditions. At the beginning of the formation there may have been no lake, only a great river with a tributary or tributaries coming in from the west; but at its close there was a great lake which stood at least sixty feet above Lake Ontario at present. Whether the change in water levels was slow or rapid there is no evidence to show. That the water remained for some time at the higher level is testified by the thorough oxidation of the iron in the upper sandy beds, which are in some layers deep brown in color, and completely cemented with limonite. The blue layers (2, 4 and 7) have retained their color because of the large amount of deoxidizing vegetable material present in them.

The change in the level of the interglacial lake effected a great change in another respect. Where the valley of the Laurentian river had existed there was now a broad and deep bay running to the north, and the great river began to spread out clay and silt derived from its upper reaches in this basin. The upper bed of blue clay may have been formed by a shifting of the current of the main river, which, however, shifted again while the highest layer of sand was formed, bringing to a close the beds belonging to the warm climate series.

The extent of the Don beds, as indicated by the typical unio sands and clays, is not known very thoroughly, owing to the depth at which they are buried in most places. They occur a few feet below Lake Ontario at Scarboro', four miles southwest of Taylor's brickyard and at Price's brickyard about half way between; and unios have been found in sandy beds of interglacial age at Adare's sand pit on Shaw street, about three miles west of Taylor's. As logs of wood have been found by well diggers at points between, there is a strong probability that the Don beds continue to that point, in which case they have a known extent from east to west of more than six miles, with a breadth from north to south of more than two miles. The real area is probably much greater than this.

THE SCARBORO' OR COOL CLIMATE BEDS

After the close of the Don period the interglacial lake deepened greatly, finally standing more than 150 feet above Lake Ontario, and a great series of clays and sands were deposited by the Laurentian river in the form of delta materials in the wide and deep bay, at this time extending still farther to the north than before. As seen at Taylor's brickyard, the clay beds, gray and finely laminated, with a few thin peaty layers, rest conformably on the brown sand at the top of the Don beds. The thickness, however, is not great, on account of later interglacial erosion, at the south end of the clay pit only 7½ feet, 70 yards north, 13 feet, and a quarter of a mile to the northeast 30 feet. These clays are magnificently shown at Scarboro' heights, where they were carefully studied by Dr. Hinde. They commence, as shown in a

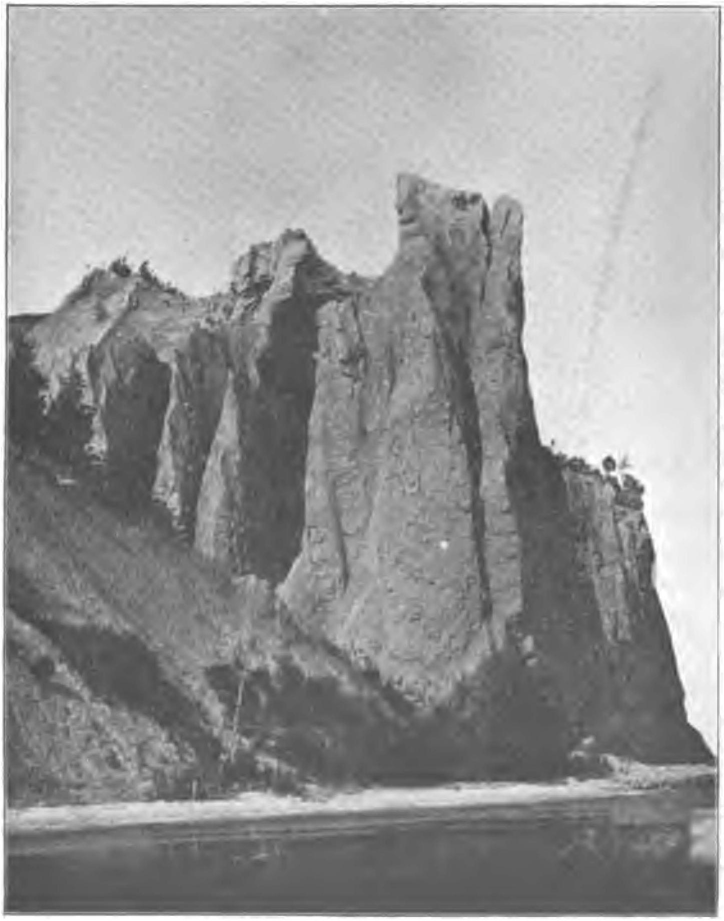


FIG. 2.—Pleistocene Cliffs of Scarboro' Heights.

well sunk on the shore beneath the cliff, about five feet below Lake Ontario and rise 85 or 90 feet above it.[1] The upper surface mingles somewhat with the overlying sand and varies in height to some extent. The clay is gray, very firm and resistant, almost as much so as the Hudson River shale of the region, and is generally finely laminated, though there are beds from two to four or five feet thick, showing little or no lamination. Besides the fine lamination there are often thin layers of grayish silt with peaty material at distances of one or two inches apart, perhaps representing flood seasons of an annual character. These silty layers cannot often be traced for more than a few feet horizontally, and may run up or down into a bed showing no lamination in a way suggesting cross bedding. Another very characteristic feature is the presence of half inch sheets of greenish impure siderite every two or three feet, though these are not found everywhere.

The silty layers with peaty substances when washed to remove clay and then dried and looked over with a lens show great uniformity in all parts of the region. Scales of mica are always numerous, as well as mosses, spruce leaves, certain round black seeds and chitinous portions of beetles. So constant is this assemblage that these clays are easily recognized by it when found in new localities, the clay ironstone sheets affording an additional earmark. Finally these are the only clays in the region which burn to a dark red brick. As their materials must have been derived by the Laurentian river and its tributaries from the calcareous bowlder clay of the valley to the north, much of the lime must have gone into solution by superficial weathering before reaching the river or have been dissolved during the time of transport, thus allowing the red color due to iron to appear on burning.

From the peaty layers of the clay the beetles were obtained whose names are given in the following lists :

---

[1] B. A. A. Sc. Rept., Com. on Pleistocene of Canada, p. 3.

Carabidae (9 gen., 34 sp.)

Elaphrus irregularis
Loricera glacialis
" lutosa
" exita
Nebria abstracta
Bembidium glaciatum
" Haywardi
" vestigium
" vanum
" praeteritum
" expletum
" damnosum
Patrobus gelatus
" decessus
" frigidus
Pterostichus abrogatus
" destitutus
" fractus
" destructus
" gelidus
" depletus
Badister antecursor
Platynus casus
" Hindei
" Halli
" dissipatus
" desuetus
" Harttii
" delapidatus
" exterminatus
" interglacialis
" interitus
" longaevus
Harpalus conditus

Dytiscidae (3 gen., 8 sp.)

Coelambus derelictus
" cribrarius
" infernalis
" disjectus
Hydroporus inanimatus
" inundatus
Hydroporus sectus
Agabus perditus

Gyrinidae (1 sp.).

Gyrinus confinis LeC.

Hydrophilidae (1. sp.).

Cymbiodyta exstincta

Staphylinidae (11 gen. 19 sp.).

Gymnusa absens
Quedius deperditus
Philonthus claudus
Cryptobium detectum
" cinctum
Lathrobium interglaciale
" antiquatum
" debilitatum
" exesum
" inhibitum
" frustum
Oxyporus stiriacus
Bledius glaciatus
Geodromicus stiricidii
Acidota crenata, Fabr. (*var.* nigra)
Arpedium stillicidii
Olophrum celatum
" arcanum
" dejectum

Chrysomelidae (1 gen. 2 sp.).

Donacia stiria
" pompatica

Curculionidae (4 gen. 6 sp.).

Erycus consumptus
Anthonomus eversus
" fossilis
" lapsus
Orchestes avus
Centrinus disjunctus

Scolytidae (1 sp.).

Phloeosinus squalidens

Dr. S. H. Scudder, who determined the beetles, thinks that all but two of the 72 are extinct. Twenty-five of the number were named a few years ago from Scarboro' material sent by Dr. Hinde, the rest more recently from specimens collected at various outcrops of the peaty clay by the writer. A complete account of the new species, with figures, will be published shortly by the Canadian geological survey. The number of species of beetles could no doubt be extended if the work of determining them were not so very laborious. In addition to the beetles cyprids occur and rarely also fragments of sphaeriums.

The plants include several trees, Professor Penhallow having found Larix americana, Picea alba and another species of Picea in materials from Price's and Simpson's brickyards; while Dr. Macoun found leaves apparently of willow and alder in peaty material from Scarboro', as well as two shrubs, Oxycoccus palustris and Vaccinium uliginosum, and some smaller plants, such as equisetum, Carex aquatilis and C. utriculata. Dr. Hinde reports five species of mosses belonging to the genera Bryum, Hypnum and Fontinalis; and Mrs. E. G. Britton adds Limnobium. Three species of diatoms, a chara and spores of lycopodium have been reported also.

Dr. Scudder judges from the relationships of the beetles to modern forms that the climate had "a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances." The same conclusion is reached by Dr. Macoun and by Professor Penhallow from the plant remains.

The change from the warm climate fauna and flora to the cool climate ones appears rather sudden, but may not be so in reality. The upper blue clay (No. 7) at Taylor's brickyard has yielded a caribou horn, which suggests a cooler climate than that of the trees and unios a few feet below, since no caribou are known within 150 or 200 miles to the north of Toronto at present. However, the range of the caribou toward the south may have been greater before the white man's settlements encroached on the region. On the other hand the materials of the delta deposits must have been derived largely from the regions to the north and from a higher elevation, where at present some trees found in the Don valley are wanting, such as Platanus occidentalis, which reaches its northern limit at Toronto.

The peaty clay occupies the western part of the great bay into which the Laurentian river emptied when the interglacial lake was at its greatest height. It appears first at Rosebank, 16 miles east of the Don, and is last seen with certainty 2½ miles west of the river in a sewer on Bathurst street, making a width of 18½ miles. Dr. Hinde reports it also from the mouth of the Humber, 6 or 7 miles west of the Don, but the writer has not been able to find it there, though somewhat loesslike sandy silt containing a few plant remains, occurring near the Humber, may represent the peaty clay of Scarboro'. If so, the whole extent of the beds will be 25 miles from east to west. The last exposure known towards the north is 6½ miles inland from Lake Ontario, and no doubt if the cuttings of the Don were deep enough it would be found considerably farther north. The greatest thickness of the clay at Scarboro' is about 94 feet, 5 below the lake and 89 above; but the upper limit is rather hard to fix, since it becomes interbedded with sand. Toward the west the peaty clay rises higher, reaching 150 feet north of Reservoir Park and in the Bathurst street sewer.

INTERGLACIAL SANDS

Above the peaty clay at Scarboro' there are stratified sands with a thickness of 55 or 60 feet where best developed near the central part of the heights, following the lower beds conformably and apparently laid down in shallower water but under similar climatic conditions. The lower 4 or 5 feet have clayey layers, but above this the sand is quite coarse, through free from pebbles, and shows cross bedding in some layers. In the sand are found all the usual minerals of Archean rocks, and a few bands of garnet and magnetite occur, evidently arranged under wave action, as on the present beach at the foot of the cliff. Just over the peaty clay there is sometimes an accumulation of coarse woody material, flattened twigs, bits of bark, etc., with quite large branches of Larix americana and Abies balsamea; and similar layers but in less quantity occur at a few points 20 or 30 feet higher up in cross bedded sand. Near the top of the sand numerous nut-like concretions of brown iron ore are found and occasionally also a few shells, such as Sphaerium rhomboideum, S. fabale, Limnaea sp., Planorbis sp., and Valvata tricarinata, but unios have not been obtained from them. The stratified sands were apparently laid down like the clays, from materials brought from the north by the Laurentian river, but in shallower water where wave action was effective, forming wide sand flats and largely filling the western side of the bay previously described. If they stretched eastwards toward the Pickering shore of the bay they must have been eroded afterwards, since they run out 8 or 9 miles from the river Don. That the stratified sand has undergone great erosion will be shown later. The sand is exposed for about 5 miles along the Scarboro' cliffs and is found overlying the peaty clay 6 miles west near Mt. Pleasant cemetery, so that it extends at least 11 miles.

A series of interglacial sands and gravels occurs in western Toronto and is well exposed in large pits near Christie and Shaw streets; but its exact relationship to the Scarboro' deposits is not certain. Where the two series meet near the corner of Dupont and Bathurst streets there are two or three beds of clay with peaty layers interstratified with sand, suggesting that the sand and gravel are of the same age as the Scarboro' clay. In the sewer opened at this point the only fossils found, beyond the remains of beetles, mosses, seeds, etc., from the peaty layers, are a few small bits of wood, which have not been determined, and the ulna of a mammoth or mastodon. The latter, however, may not belong to these beds, since it has been smoothed and scratched by glacial action, and may have lain on the surface at the time of the Wisconsin ice advance.

In the sand and gravel pits half a mile to the west no clay is to be seen and it is not certain whether the beds correspond to the warm climate period of the Don, or to the cool climate period of Scarboro', or include the equivalents of both periods.

At Mr. Adare's sand pit a considerable number of fossils have been obtained, including numerous campelomas, two or three species of pleurocera, Valvata sincera, two or more species of sphaerium, and fragments of unios, all shells which occur in the Don beds. Beside these fossils bits of elephant tusks and a large atlas vertebra, probably of Bison americanus occur, but none of the species is decisive as to climate, though the mammoth or mastodon suggests a cool climate.

The sand and gravel beds have a thickness of at least 78 feet and rise 130 or 140 feet above Lake Ontario, but their extent is unknown, as they are in general buried under bowlder clay. It is certain that these beds were formed under different conditions from those either of the Don or Scarboro'. They are of coarser and more variable materials, often showing very marked cross bedding, probably produced by currents rather than waves, and sometimes apparent unconformities such as are made by a stream changing its bed. We may suppose that an interglacial Humber river coming in from the west or northwest brought down sand and gravel at the edge of the great bay, mingling them at some points with the clayey delta materials of the Laurentian river.

This brings to a close the series of deposits composing the Toronto Formation. In all there are four varieties, the sands and clays of the Don with their warm climate trees and Mississippi unios; the peaty clays of Scarboro' with their seventy extinct beetles and their small flora, suggesting a cool, but not arctic climate; the stratified sands overlying them, probably forming a continuation of the cool climate period; and the western sands and gravels with elephants, bisons and some shellfish affording little evidence as to climate. The maximum thickness observed in each set of deposits is as follows:

3. Scarboro' sands - -	60	feet.	4. Western sands and gravels, 78 ft.
2. Scarboro' peaty clays	94	"	
1. Don beds - -	41½	"	
	195½		

The greatest thickness measured at one place is at Scarboro'

Heights where 150 feet of cool climate beds overlie 36 feet of warm climate beds, making 186 feet in all. However as the 36 feet of unio sands and clays commence 5 feet below the level of Ontario and its water filled the well sunk there before the bowlder clay was reached, it is certain that the Scarboro' section contains more than 186 feet of interglacial beds, but how much more cannot be told. It is probable also that the upper sands once reached higher than at present, since their surface evidently underwent great erosion before the overlying bowlder clay covered them.

DRAINING OF THE SCARBORO' LAKE

At its highest point the great interglacial lake must have stood more than 150 feet above Ontario, since the upper beds of the cold climate deposits reach 152 feet. Then came a fall in the level, whether sudden or slow is uncertain, though a slow drainage seems more probable. The cause of the original rise of the water was probably the elevation of the lower part of the Laurentian river valley, near the Thousand Islands. If so we may suppose that the rise of the northeastern portion of the continent was slow, as it is at present; and it may not have gone on at a uniform rate, for there seems to have been a halt at 60 feet above the present lake. If the rise was slow the sinking of the barrier at the Thousand Islands at the close of interglacial times was probably equally deliberate. Ultimately the water fell below the present level of Ontario, as shown by the erosion of interglacial valleys in the strata of the Toronto Formation; but whether the lake was completely drained so as to restore the open valley with its great river or was only partially drained is uncertain.

With the lowering of the lake the channels of the rivers must have been rearranged, for the old bay was now largely filled with clay and sand; and in the Scarboro' section there is evidence of the cutting of three valleys through the stratified sand and peaty clay. The one to the east, where the River Rouge and Highland Creek now flow, was cut down below the present level of lake Ontario for about five miles, probably by the Laurentian river, which seems to have shifted its bed towards the east as the lake level sank, to avoid the thickest part of the previously formed delta. As no peaty clay has been found in the cuttings made by the Rouge and Highland Creek, but only bowlder clay and later stratified clay and sand, this interglacial valley seems to have been extensive.

Walking westward from Highland Creek the slope of the old valley is seen to rise gently, first the peaty clay showing above the water and becoming thicker and thicker, and then the overlying sand showing itself, finally reaching its maximum thickness about four miles from the first appearance of the peaty clay on the lake shore. How much of the valley already existed before the river began its work is unknown, but at least a considerable thickness of the tough peaty clay must have been cut through, for at Rosebank to the east of the old valley it rises 20 or 30 feet above the lake.

Continuing westward along the shore a second much narrower valley still buried under till and unfossiliferous stratified clay is seen at the "Dutch church," as a vertical promontory three miles from the western end of the Scarboro' section has been called. This "fossil" valley was cut through the full thickness of interglacial sand and clay to a level below the present lake, on the shore of which it shows a width of about 1200 feet. At the top of the peaty clay, 90 feet above the lake, its width is about double this; and its sides then slope gently up to the top of the stratified sand with a total width not much short of a mile. The Dutch church valley was apparently made by a comparatively small stream.

It should be mentioned, however, that Professor Albrecht Penck gives another explanation of the downward dip of the bowlder clay at this point, supposing that the promontory is really a mass of till lodged to the south of an old lake cliff of interglacial times. The old cliff has been exposed again on each side of the Dutch church by the action of the present lake, but the tough clay at that point has resisted better and still remains.

According to this view, after the Scarboro' beds were deposited the water sank to a level below that of the present lake and remained there long enough to cut back the mass of delta deposits to about the position of the present cliff. Although the first explanation seems the more simple, the one given by Professor Penck deserves careful consideration. At present there is not evidence enough to settle positively which is correct.

Toward the west of the Scarboro' exposure the stratified sand gradually thins and disappears beneath the bowlder clay and the same is afterwards true of the peaty clay, which sinks below the lake at Victoria park at the east end of Toronto. Here probably another wide valley was cut, though its western shore is not seen distinctly. The upper stretch of the Don Valley, which turns to the east after emptying into Toronto Bay, discloses only till and the overlying unfossiliferous beds in its ravines, though peaty clay rises to 152 feet near Mount Pleasant cemetery toward the west, and to nearly 100 feet at Price's brickyard to the southeast, suggesting an old river valley between, perhaps of an interglacial Don. The form of this valley is not so well worked out, however, as in the case of the other two.

As no interglacial deposits have been found clearly belonging to this later low water stage, there is no evidence as to the climate during the latter part of the interglacial time; but we may suppose that it grew colder until the region was once more covered with an ice sheet, probably corresponding to the Wisconsin till of the states to the southwest.

LATER GLACIAL DEPOSITS

The earlier (Iowan) ice advance found little obstruction in the region of Toronto and passed over leaving only a comparatively thin sheet of bowlder clay, not greatly modifying the general form of the surface; but the later glacial invasion took place under changed conditions. The broad Georgian Bay — Scarboro' Valley through which the Laurentian river had flowed, was now largely blocked with the great interglacial delta deposits, which no doubt stretched as a tongue some miles in length out into the valley of the present Lake Ontario. The lower part of these deposits consists of very firm stratified clay strengthened by sheets of clay ironstone; but at the eastern end of Scarboro' Heights the clays have been greatly crumpled and contorted, and even large blocks shifted and tilted, by the pressure of the on-coming Wisconsin ice. As the delta seems to have run about southeasterly it lay almost directly athwart the course of the advancing ice, which, after crossing the later valley of the Laurentian river, had to climb over a ridge at least 150 feet in height, and probably considerably higher, before proceeding on its way diagonally across the Ontario Valley. This obstruction, perhaps aided by climatic variations, seems to have kept the ice more or less in check. Meantime the lower end of the Ontario Valley must have been blocked with ice so that the water once more rose assorting the "rock flour" furnished by subglacial streams as gray stratified clays without fossils overlying the uneven surface of bowlder clay covering the series of ridges and valleys left by the interglacial rivers.

The halt at the Scarboro' delta was long and must have included at least three great oscillations of retreat and advance to account for the complex of tills separated by stratified materials now crowning the heights. The first sheet of till is shown for about nine miles continuously at Scarboro' with the shape of a slightly bent bow, touching the lake at each end and with a sharp downward dip at the Dutch church. The latter is, however, less symmetrically placed than in a bow, being only three miles from the west end and six from the east.[1] The hollow of the Dutch church valley was filled with till containing compartively few stones to a level 50 or 60 feet above the present lake, then merging into gray stratified clay which rises to a height of 165 feet, where it is covered with a few feet of much later Iroquois beach gravel. Very similar clays rising to the same height or a little higher are found at brickyards to the north of Toronto. They burn to a gray brick and so are easily distinguished from the peaty clay which makes red brick.

---

[1] See diagram, JOUR. GEOL., Vol. III, No. 6, 1895, p. 624.

The highest part of the Scarboro' escarpment, about a mile east of the Dutch church, gives the best section of these complex glacial deposits. At the point where the old Iroquois beach is cut off for a distance by the present lake cliff, there is a face of 270 feet displaying three layers of bowlder clay separated by stratified sand, the whole overlying the stratified fossiliferous sands of the Toronto Formation. A few hundred yards to the east of this the escarpment reaches its highest level, 354 feet above the lake, but the lower part is not so well shown. The upper portion is, however, more complete, since overlying the third till sheet one finds laminated grayish blue or purplish clay followed by evenly bedded fine sand, on which rests a fourth bowlder clay. Putting the two sections together we have the following complete section :

	Feet	
Bowlder clay No. 4 - - - - - -	48–354	203 feet Glacial Complex
Stratified sand overlying stratified clay	36–306	
Bowlder clay No. 2 - - - - - - -	32–270	
Silty sand, the upper layers crumpled	25–238	
Bowlder Clay No. 3 - - - - - - -	9–213	
Cross bedded sand - - - - - - -	29–204	
Bowlder clay No, 1 - - - - - - -	24–175	
Fossiliferous sand - - - - - - -	59–151	151 feet, Toronto Formation
Peaty clay - - - - - - - - - -	92– 92	
Lake Ontario - - - - - - - - -	0	

The whole series of tills with the interstratified sand and clay at Scarboro' amounts to 203 feet in thickness and implies a glacially dammed lake reaching more than 300 feet above Ontario. The highest stratified materials in the neighborhood of Toronto occur, however, at the North Toronto waterworks, 360 feet above the lake, where a well showed several beds of clay alternating with sand and gravel, probably equivalent to some of the beds at Scarboro'.

No fossils have been found in the sands or clays of the glacial complex at Scarboro', but a few have been picked up in stratified sand lying between two beds of bowlder clay at the

Metropolitan power house, a mile or two north of Toronto, Amnicola limosa, a Succinea and fragments of another species. These occur at 220 feet above the lake, but the sand containing them runs up to 247 feet and may correspond to the silty sand between till No. 2 and till No. 3 at Scarboro'.

One of the recessions of the ice, perhaps the one just mentioned, appears to have been very extensive, for two thick beds of bowlder clay are found to be separated by stratified materials at numerous points on the lake shore as far east as Newtonville, fifty miles from Toronto. The same relationship is found near the headwaters of the Don, about eight miles north of the city, and also in ravines to the east, but has not been observed to the immediate west; though the stratified clays lying between two layers of till at Dundas and at several points near Niagara Falls may correspond to the same interglacial stage. In that case the ice must have withdrawn eighty miles in a northeasterly direction before advancing again.

During the first recession of the ice the lake was dammed to a level at least 160 feet above the present, for roughly stratified grayish clay with a few small polished and striated stones is found at many points at about this level, filling in hollows of the bowlder clay, as at the Dutch church and Taylor's brickyard. Afterwards, as shown above, the water stood much higher, since stratified materials are found 360 feet above Ontario or 606 feet above the sea, and may have formed part of a large body of water, covering Lake Erie as well as the western end of Ontario. As the whole of these stratified clays and sands were afterwards overridden by the ice and covered with the latest sheet of till they must be looked on as interglacial. The highest bowlder clay has not yet been traced with certainty west or south of the Toronto region, however, since the four sheets of bowlder clay are very much alike and cannot be discriminated when found alone; and there is a possibility that it ends here, and that the water then filling the Ontario basin was continuous with that of some of the successors of Lake Warren. If so, beach lines may have been formed to the west or south of Lake Ontario while the last till was being spread over the upper interglacial beds here described. Professor Fairchild places the Warren beach south of Lake Ontario at 880 feet, and his next important water level, Lake Dana, at about 700 feet, both far above the highest interglacial stratified sand or clay at Toronto.[1]

CONCLUSIONS

One who studies the complex set of glacial and interglacial beds of the Toronto region is strongly impressed with the length of time demanded for their production. There is no reason to suppose that the withdrawal of the Iowan ice and the drainage of the waters which it dammed were more rapid than the similar series of events following the latest ice sheet. When the Toronto beds began to be formed the water level in the Ontario valley was probably lower than now in Lake Ontario, and some erosion had already taken place in the Don valley and at other points. There had been time for the warm climate plants to return from exile in full force and for forest trees of a most varied kind, though mainly deciduous, to grow and fall on the banks of the rivers. The unios, too, had already migrated north from the Mississippi stronger in species than they are now. All this may imply as long a time after the Iowan ice sheet withdrew as has elapsed since the last ice sheet departed, before the lowest beds of the Toronto Formation were even begun.

Then came the raising of the rocky barrier at the eastern end of the Ontario basin to sixty feet above the present level, and a halt at that level while the upper sands became browned and cemented with limonite. The climate grew cooler ~~and~~ and then ninety-four feet of clay and fifty-five feet of stratified sand were laid down at Scarboro', the eastern barrier rising meantime to 152 feet above the present level.

Then there was a halt in the elevation toward the northeast and at length a reversal of the motion, the northeastern end of the basin being depressed until the great Scarboro' lake was drained to a level probably much lower than that of Ontario at present, and river valleys were eroded through 150 or 250 feet of sand and clay and widened so as to have gentle slopes.

---

[1] Bull. Geol. Soc. Am., 1899, p. 31 and p. 56.

It will be observed that the damming of the interglacial waters is held to be due to epeirogenic changes and not to the presence of ice, since it is inconceivable that an ice dam should hold its place at the Thousand Islands during the ages of mild climate required for the growth of the luxuriant Don forests, largely composed of trees that now barely reach the southern edge of Canada.

It is not unfair to assume that the time after the Iowan ice retreated until the commencement of the Toronto Formation was as long as from the retreat of the Wisconsin ice to the present, a time variously estimated at from 7000 to 30,000 years. The raising of the northeastern barrier of the Scarboro' lake to a height at least 150 feet above that of Lake Ontario may also have required thousands of years, if the results of Dr. Gilbert's investigations as to the rate of tilting of the present lake basins furnish the standard. These two stages cover only the first half of the interglacial time, and probably an equal number of thousands of years were required for the depression of the outlet below that of Lake Ontario and the cutting of wide and deep valleys through the Toronto Formation.

To arrive at the total length of the interglacial period it is not extravagant to double or even triple the number of years since the last Ice age, giving estimates of from 14,000 to 60,000 years or more. It will of course be understood that the length of time since Niagara began to cut its gorge can be estimated only vaguely and that the guess at the length of the interglacial period given here is still less certain.

How long a time the later series of bowlder clays and interstratified materials, more than 200 feet thick at Scarboro', required in their formation one can hardly even guess; but one of the glacial retreats amounted probably to more than 50 miles and may alone have demanded centuries of recession and advance.

The time element in the series of events described has been somewhat strongly insisted on in this paper, since many geologists who have worked only in regions where the Pleistocene deposits are relatively simple in structure and not of great thickness are apt to underrate the importance of interglacial periods, looking on them as short episodes of retreat and advance in the history of a single Ice age. The evidence adduced here points to completely distinct Ice ages, separated by thousands of years of mild climate. It is not improbable that the present time is merely another interglacial period.

An interesting result of the action of rivers and ice is found in the change of relief in the region since the Iowan ice departed. The valley of the Laurentian river, then probably a hundred feet or more below the present level of Lake Ontario, is now replaced by Scarboro' Heights rising 350 feet above the lake and presenting the highest cliffs on its whole shore.

A summary of the best marked stages in the Pleistocene history of the region is given below, special reference being made to climates and water levels. The latter are of course not absolute levels but only relative, since the region as a whole probably underwent important elevations and depressions during Pleistocene times.

STAGES OF TORONTO PLEISTOCENE

1. Retreat of the Iowan ice sheet.
2. Interval of erosion with water probably lower than at present.
3. Don stage, warm climate trees and Mississippi unios, water dammed by differential elevation toward the northeast to 60 feet above the present lake.
4. Scarboro' peaty clays, cold temperate climate, with trees and mosses and 70 species of extinct beetles, formed as delta by Laurentian river in interglacial Scarboro' bay.
5. Scarboro' stratified sand with some trees and freshwater shells of cold temperate climate, delta completed, lake stands 152 feet above the present.
6. Water drawn off by lowering of outlet, subaerial erosion of previous beds, and cutting of river valleys more than 150 feet deep,
7. Advance of Wisconsin ice front raising the water to about 160 feet as shown by stratified interglacial clay, retreat for 50 miles and re-advance, followed by two later retreats and advances, the water finally rising 360 feet above the present lake.
8. Final retreat of ice sheet, followed by water levels of lakes Warren and Iroquois and a brief entry of the Gulf of St. Lawrence into the Ontario basin, which, however remained fresh.

A. P. Coleman.

PROBABLE REPRESENTATIVES OF PRE-WISCONSIN TILL IN SOUTHEASTERN MASSACHUSETTS

INTRODUCTION

In the central portion of the country, where the glacial deposits are spread out in a general northward retreating series of sheets, the tills of the various ice invasions have long been differentiated and classified chronologically with a considerable degree of certainty. In New England, however, each of the prominent advances reached nearly or quite to the southern limit of the area. The repeated passage of the ice over the region, and the consequent severe glaciation to which it has been subjected, has served to remove far more thoroughly than in the region further west the evidences of pre-Pleistocene conditions and of early Pleistocene tills. Under such conditions of glaciation, the preservation of remnants of the early tills would be very exceptional, and it is not strange, therefore, that deposits of these early tills have not previously been found.

While severe glaciation is the rule in New England, the action has by no means been of the same severity throughout the area. The area may be divided into three parts: (1) a northern belt characterized by severe and almost universal erosion with correspondingly little deposition; (2) a middle belt with generally moderate, though sometimes locally severe glaciation, but characterized as a whole by a marked deposition of subglacial till as attested by its drumlins; and (3) a southern belt of generally weak erosion, except in the more exposed localities, accompanied by a comparatively slight deposition of till. This southern belt, the northern limit of which in eastern Massachusetts is a few miles south of Boston, is nearly or quite destitute of drumlins, rarely shows any evidences of severe glaciation such as characterizes the northern belt, and is marked by the occurrence of numerous instances of pre-glacially decayed rock surfaces.

It was while engaged in field work on the surface geology of this southern belt that the writer first encountered exposures of till of a type entirely unlike that ordinarily prevailing over this part of New England. In composition, in color, and in weathering, the till in question was strikingly different from the ordinary buff till of the region, and had the aspect of being much older than the latter. A further study of its character and associations was found to corroborate the differences first noted, and apparently warranted the conclusion that it should be considered as representing the deposits of an ice sheet which certainly antedated the last invasion, and probably marked the earliest of the Pleistocene advances.

The area embracing these tills is located in the eastern and central portions of the Dedham quadrangle of the United States geological survey at a distance of some twenty miles south of the city of Boston. The position of the quadrangle and of the area of the till localities is shown in Fig. 1.

It will be seen from this map that the tills are situated some fifteen to twenty miles inside of the interlobate moraine near Plymouth, and at a distance of some fifty miles north of the line of the corresponding terminal moraine. This moraine, for in origin it is a unit, is usually correlated chronologically with the Wisconsin. If this is so, and there are apparently no grounds for doubting the conclusion, it is evident that the till sheet which covers the surface of this portion of Massachusetts to an average depth of perhaps five to fifteen feet, and which is clearly contemporaneous with the moraine, is likewise of Wisconsin age.

Observations on Massachusetts glacial deposits of an age earlier than those of the last ice advance have been few in number and, with the exception of occasional instances of the burial of stratified drift deposits beneath later tills, have been confined to the vicinity of the moraines along the south coast where the conditions for differentiating the glacial deposits are more favorable than in the inland area to the north.

Before considering the evidences of older tills which the writer believes he has discovered beneath the Wisconsin till sheet, mention will be made of a number of papers presenting evidences of possible interglacial phenomena or of plural tills in this part of New England.

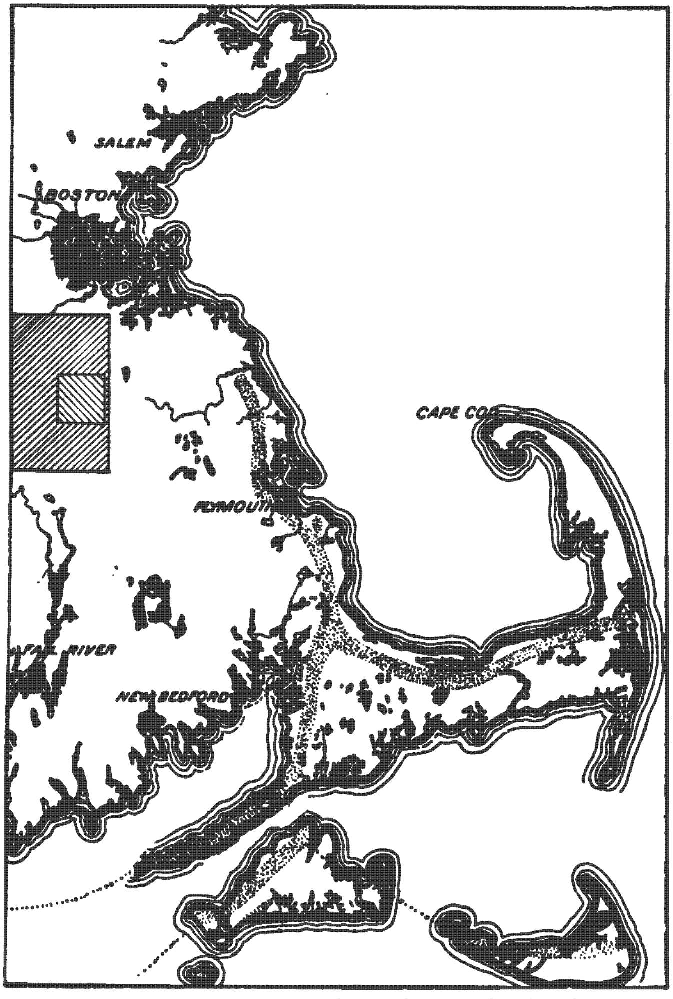


FIG. 1.—Sketch map of southeastern Massachusetts, showing the location of the Dedham quadrangle and of the special map of till localities (Fig. 2).

One of the first papers describing occurrences suggestive of interglacial deposits was that published by W. W. Dodge[1] in

---

[1] Some Localities of Post-Tertiary and Tertiary Fossils in Massachusetts. Am. Jour. Sci., Series III, Vol. 36, pp. 56, 57.

1888. Though not recognizing the true nature of the material, he described a section of the Great Head Drumlin of Winthrop, a few miles northeast of Boston, and showed that beneath the great mass of clayey material, now known to be till, it possessed a core of fine loose gravel rising several feet above the base of the section (sea level), and containing fossil fragments of Venus mercenaria and other species identical with those existing in the waters of the harbor at the present time.

In 1888, Upham[1] also referred to the presence of the core of modified drift in the drumlin at Great Head, Winthrop, and announced the presence of similar cores in drumlins at Third and Fourth Cliffs at Scituate, some twenty-five miles southeast of Boston. No evidence as to age was brought forth beyond the fact that the stratified deposits were of glacial origin and antedated the ice advance, supposedly the last by which their till coating was deposited.

Shaler[2] was probably the first in Massachusetts to call attention prominently to the occurrence of two distinct tills separated by a long interglacial period. According to him the deposition of the oldest formation of Nantucket, which he describes as a blue pebbly clay till was followed by a long period of submergence and the deposition of fossiliferous marine beds, after which the ice again advanced, partly eroding the marine beds and giving rise to the well-known morainic deposits of the north shore of the island.

In his paper on the "Structure of Drumlins"[3] Upham, in 1899, gave a detailed description of the drumlins of Third and Fourth Cliffs at Scituate and illustrated the descriptions by sections, one of which showed the presence of till both above and beneath the stratified core of the drumlins. The section apparently demonstrated that the stratified deposits were interglacial, at least in the narrow sense of the word, for they were evidently deposited between an earlier and a later ice advance. The two tills, however, were identical in character, and presented nothing indicative of any considerable time interval between their deposition. The tills and the included stratified drifts are probably to be regarded simply as marking local variations of the same general invasion. Drumlins in which layers of modified drift are inclosed in the till were also mentioned as occurring in other parts of Massachusetts and in New Hampshire and New York.

---

[1] Marine Shells and Fragments of Shells in the Till near Boston. Boston Soc. Nat. Hist. Proc., Vol. XXIV, pp. 127-132.

[2] The Geology of Nantucket, U. S. Geol. Surv., Bull. 23.

[3] Boston Soc. Nat. Hist., Proc., Vol. XXIV, pp. 228-242.

The descriptions of the drumlins at Scituate were repeated by Upham in 1894 in his paper on the "Madison Type of Drumlins,"[1] but no new facts of importance bearing upon glacial conditions in Massachusetts were presented.

In the table and descriptions accompanying his paper on the clays of Rhode Island and southeastern Massachusetts Woodworth,[2] in 1896, gave three glacial epochs. The first and second were separated by the deposition of the fossiliferous marine gravels, sands, and clays of the Sankaty sub-epoch, as was recognized by Shaler on Nantucket. The second ice invasion, which is apparently assumed (p. 977) as the cause of the strong folding of the Cretaceous, Tertiary, and early Pleistocene strata of Gay Head, etc., and the last invasion are separated by what is designated as the Vineyard interval of extensive subareal erosion, accompanied by deposition below the present sea level.

In the chapter on the clays about Boston, Marbut and Woodworth[3] give reason for believing that the clays were probably of esturine or marine origin, and were deposited in connection with a previous ice invasion. Several sections are described and illustrated which show that the clays are in a number of cases overlain by drumlins which were formed during the last ice advance. The clays frequently present evidences of strong erosion, probably due largely to the action of over-riding ice

---

[1] Am. Geol., Vol. XIV, pp. 69–83.

[2] The Glacial Brick Clays of Rhode Island and Southeastern Massachusetts: The Geology and Geography of the Clays. U. S. Geol. Surv., Seventeenth Ann. Rept., Pt. I, pp. 975–988.

[3] Loc. cit., pp. 989–998.

(p. 991). According to the evidence presented, the clays are contemporaneous with an earlier ice advance, and are clearly older than the last, but nothing definite as to the length of time intervening is known.

In 1898, Shaler in his paper on "The Geology of the Cape Cod District,"[1] again recognized the existence of two tills, between the deposition of which a period of great length intervened. In this interval he recognized the deposition of three sedimentary formations:[2] the Nashaquitsa, the Barnstable, and the Truro, each of which was followed by prolonged periods of aqueous erosion. This interglacial time was regarded as vastly longer than that which has elapsed since the disappearance of the ice of the last invasion.

DESCRIPTION OF TILL EXPOSURES

The ordinary till exposures in southeastern Massachusetts present the following characteristics. At the top lies a light buff till consisting of the usual heterogeneous mass of clay, sand, and bowlders. The percentage composition of this till varies within wide limits, especially in regard to the quartz-flour and clay constituents which range from a combined amount of perhaps 10 per cent. or less in some of the tills in the southern portion of the state to an average total of some 55 per cent. in the drumlins about Boston.[3] In most sections the till is moderately oxidized from top to bottom, as indicated by its buff color, but where natural or artificial cuts have exposed it to any considerable depth it is found to pass downward into an unoxidized portion of a gray or bluish-gray color, usually designated as blue till. The depth to which the oxidation extends presumably depends somewhat on the percentage of the clay constituent of the till. Though the oxidation is very much less conspicuous in tills high in sand, the depth to which the oxidation extends is probably greater than in the more clayey tills. In the Boston drumlins, which are high in clay, the oxidation has usually reached a depth of some twenty feet. Where the bedrock upon which the tills rest is exposed to view it is ordinarily found to present well glaciated surfaces, showing no traces of decomposition beyond a thin superficial zone seldom more than half an inch in thickness, and often represented only by a slight surface discoloration.

---

[1] U. S. Geol. Surv., Eighteenth Ann. Rept., Pt. II, pp. 497–593.

[2] Loc. cit., pp. 535–538.

[3] W. O. Crosby: Composition of the Till or Bowlder Clay. Boston Soc. Nat. Hist. Proc., Vol. XXV, p. 25.

CENTER STREET EXPOSURE, BROCKTON

In marked contrast to the section just described are the sections exhibited by the older tills observed by the writer. The first of these old tills to be observed was exposed several years ago during excavations for the foundations of one of the heavy stone arch bridges which were necessitated by the abolishment of the grade crossings of the New York, New Haven and Hartford Railroad. (Fig. 2, Exposure 1.) The first six feet or so from the surface was of the ordinary slightly oxidized buff till of the last, or Wisconsin invasion, but on going deeper, instead of becoming lighter and gradually merging into the unoxidized blue till as in the ordinary typical section, the buff till gave place abruptly to a mass of distinctly red and yellow till. This till at the time it was seen by the writer was exposed to a depth of about four feet, but was later excavated to a depth of from two to four feet more, at which point it was found to rest on a deeply decomposed and highly oxidized conglomerate of Carboniferous age. Besides its high colors, due to the advanced state of oxidation, the lower till was found to differ in a marked degree in composition from the ordinary buff till. Clay, including quartz-flour, which in the overlying till forms less than one half of its bulk, constitutes nearly the whole of the lower till. The pebbles of the upper till comprise some 25 per cent. or more of its mass and are varied in type, complex in composition, fresh in appearance, and have often been transported considerable distances. In the lower till, on the other hand, the pebble component probably never exceeds 10 per cent. of the mass, and only the resistant quartz and quartzite pebbles from the underlying rock are usually represented. The buff till is without visible structure, while the lower oxidized till is characterized by a distinct, but rude and highly irregular lamination.

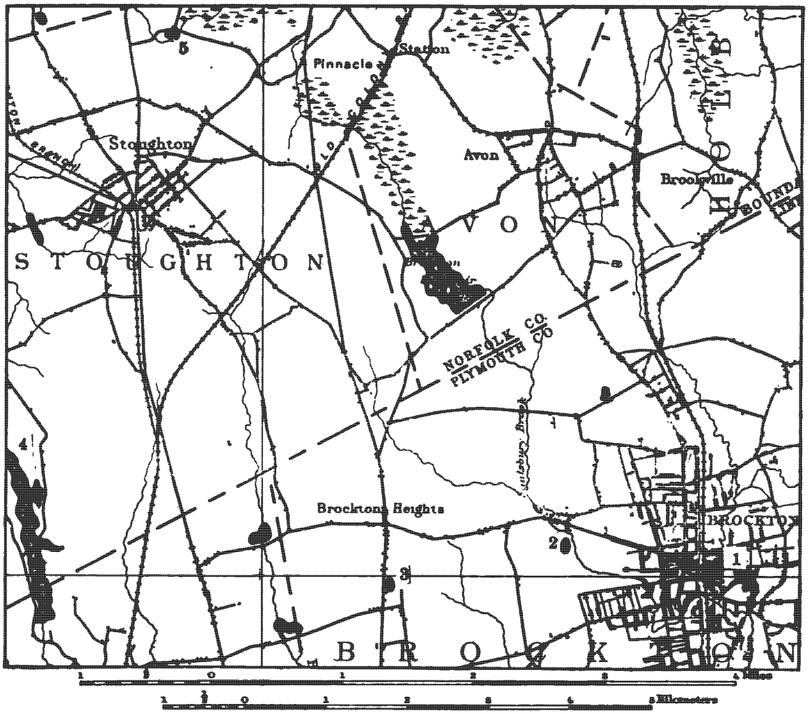


FIG. 2.—Map[1] showing location of exposures of tills of probable Pre-Wisconsin age. 1. Center street exposure, Brockton; 2. Intervale Park exposure, Brockton; 3. Pearl street exposure, Brockton; 4. Ames pond exposure, Stoughton; 5. Pine street exposure, Stoughton.

The derivation of the lower till from the underlying decomposed conglomerate is plainly indicated by its color and composition. This conglomerate is composed largely of pebbles of granite, black slate, quartzite, and some quartz,[2] embedded in a somewhat feldspathic sandy matrix. It exhibits a rather perfect cleavage at right angles to its stratification. Where so situated as to be exposed to the full action of the ice at the time of the last invasion, it exhibits smooth, hard, and well glaciated surfaces of a dark gray color with almost no evidences even of superficial oxidation. In less exposed positions, such as exist along the well defined valley running southward through the city of Brockton just east of the center, the glaciation was apparently exceedingly slight. It is in such positions that the decayed conglomerate from which the lower till was derived is found. At the surface the conglomerate presents the high colors of advanced oxidation, but somewhat irregularly arranged owing to variations of the original composition of the rock. Some of the portions free from iron give on decay spots or streaks of an almost white sandy clay. The predominating color is a distinct yellow, interspersed with red in many places. The rock is so soft at the surface that it can sometimes be removed by pick and shovel. The depth of the extreme decay is somewhat variable, possibly averaging from two to three feet, though it is probably considerably greater in places. From the highly decayed portions, the rock passes downward by insensible gradations into less altered portions, but in none of the shallow excavations which the writer has seen has fresh rock, such as is exposed where the glaciation has been severe, been reached. The decomposed conglomerate probably underlies most of the low region near the center of the city and has been exposed in the laying of water pipes, drains, sewers, etc., along Center and Crescent streets and near the high-school building on Main street. Many of the excavations in which decomposed conglomerate was exposed were made ten or more years ago, and though the presence of the decayed rock can be vouched for, the writer cannot say with certainty that it was everywhere overlaid by the oxidized till, though later observations suggest that such was probably the case.

---

[1] Reproduced from special edition of the Dedham quadrangle of the U. S. Geological Survey. Presented through the courtesy of Professor W. O. Crosby and the Boston Society of Natural History.

[2] Quartz also occurs in considerable amounts in the numerous small veins cutting the conglomerate.

It is certain that the deep rock decay antedates the last ice invasion. If this decay is the result of pre-Pleistocene weathering, the evidence naturally leads to the conclusion that the overlying oxidized till evidently derived from it was the result of the re-working of the soft decomposed material by the first ice advance, in which case it is probable that it should be correlated with the Kansan or pre-Kansan glacial deposits of the central portion of the country. If, on the other hand, the rock decay is considered as of interglacial origin it constitutes of itself an evidence of a long interglacial period. This last supposition, however, cannot be maintained, for the rock weathering is far too extensive, reaching downward as it does to a depth of some feet, to have been brought about in interglacial times.

An alternative supposition which naturally suggests itself is that the oxidized till may after all be considered as of Wisconsin age, and as representing the re-working of the pre-Pleistocene decomposed rock material which had somehow been preserved from the erosive action of the earlier invasions. In answer to this it may be urged that, while the actual erosive power of the earlier advance was comparatively slight, it is almost impossible to conceive of an ice sheet so weak that at a point more than fifty miles from its margin it passed over soft decomposed rock material without re-working it in any degree, especially as till deposits of the corresponding advance occur along the outer margin at Nantucket sixty miles further south. A further and apparently fatal objection to the consideration of the oxidized till as of Wisconsin age lies in the fact that, in the re-working of the previously decayed rock and soil by a sheet known to be specially characterized by numerous foreign fragments, there would at least be a gradual transition between the highly oxidized and the ordinary type of till. In reality, however, the contact is so sharp that the breadth of a hand will usually, and sometimes more than cover it.

INTERVALE PARK EXPOSURE, BROCKTON

At the time of the laying out and leveling of the tract of land known as Intervale Park, about a mile west of the Center street locality, a number of good sections of till were transiently exposed. One of these sections (Fig. 2, Exposure 2) showed a yellow and red oxidized till, almost identical in appearance with the one previously described and lying in a corresponding position beneath the ordinary buff till. The general character of the exposure is shown in Fig. 3, in which the horizontal and vertical scales are the same.

In composition the lower till was similar to that of the Center street exposure, being probably as high as 70 or 80 per cent. in clay and quartz flour. Like the first, it was evidently derived from the underlying conglomerate and showed the same quartzite pebbles and the same yellow and red colors. The prevailing color, however, was somewhat lighter, yellow and gray predominating. Like the Center street exposure it was irregularly laminated and separated from the overlying till by a sharp and distinct line of demarcation.

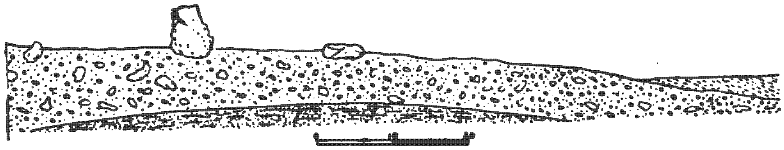


FIG. 3.—Section showing the relations of the older and younger tills in the Intervale Park exposure, Brockton. (Exposure 2 of Fig. 2.)

With a view to comparing with other tills, samples of the oxidized till were collected and examined as to their composition. In the following table the results of the examination are given and compared with the immediately overlying till, and with the till of drumlins in the vicinity of Boston:

	Bowlders and gravel	Sand and quartz flour	Clay
1. Highly oxidized clay-till[1] - - - - -	10	68	21-23
2. Ordinary till overlying the above[2] - - -	50	45	5
3. Clay-till of Boston drumlins[3] - . - -	25	63	12

Attention is especially called to the clay constituent which in the lower till is about four and a half times as great as in the overlying till and nearly twice that of the tills of the drumlins, which represent the most clayey tills previously known. The difference in the amount and character of the included rock material is also very marked. The lower till was found to contain only about 10 per cent. of pebbles, mainly under an inch in diameter and consisting principally of quartzite. The upper till contained some 50 per cent. of pebbles and cobbles, besides a large number of massive bowlders of granite and diorite varying from five to ten or even twenty feet in diameter.

---

[1] Clay determined chemically, others estimated from physical examination.

[2] Estimated from physical examination.

[3] Average of sixteen careful physical analyses by W. O. CROSBY, Boston Soc. Nat. Hist., Proc., Vol. XXV., p. 124.

The underlying rock was not exposed in the immediate vicinity of the till here described, but it is known to be a conglomerate similar in character to that of the Center street locality, and to be likewise considerably decomposed.

The great dissimilarity of the lower till from the overlying till, the sharp line of demarcation between the two, the evident derivation of the former from deeply decomposed conglomerate, and the exceptionally close resemblance of the lower till to that of the Center street exposure, have led the writer to correlate it with the latter and to refer it to the same early Pleistocene invasion.

PEARL STREET EXPOSURE, BROCKTON HEIGHTS

The writer's attention was called to this exposure of what may probably be considered as a representative of pre-Wisconsin till by Mr. M. S. W. Jefferson, of Brockton, to whom the credit of the discovery of the locality is due. The exposure was within a gravel pit of some size on the south side of Pearl street, a short distance north of its junction with Rockland street (Fig. 2, Exposure 3).

The height of the section was about five feet, of which the upper two feet was of the ordinary type of buff till containing numerous bowlders. The lower three feet was of an entirely different and somewhat remarkable character, being composed of an arkose-like mass of disintegrated material evidently derived from the coarse porphyritic granite which is known to underlie it. At first sight it bears a slight resemblance to a granite disintegrated *in situ*, but a closer examination reveals the presence of sand and pebbles of foreign material, showing that it is to be regarded as a true till in which, as in the two tills already described, the material is almost entirely derived from the underlying rock. The color of the mass is a dirty, somewhat rusty brown, there being no trace of the higher colors exhibited by the tills previously considered. The line of demarcation between the two tills is much less sharp than in the preceding instances and is due to the predominance of the same granitic material in both tills. The chief difference is that in the lower till the granite is present as a disintegrated arkose-like mass, while in the upper till it occurs in a fresh condition and largely as glaciated pebbles or bowlders.

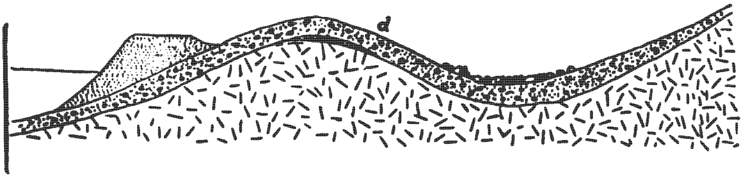


FIG. 4.—Section showing general relations of granite, till, and drift terrace at the Ames Pond exposure, Stoughton. Vertical scale, about 200 feet to an inch; horizontal scale, about 50 feet to an inch.

AMES POND EXPOSURE, STOUGHTON

This exposure is in a gravel pit on the east side of the pond north of the small bay which comes up to the highway (Fig. 2, Exposure 4). The general section of the locality is shown in Fig. 4. The till to be described is exposed on the east slope of the rock and till ridge at *d*.

The lower till is somewhat similar to that in the Pearl street exposure at Brockton Heights, the material being a pink granite. The chief point of difference, perhaps, lies in the fact that the till of the Ames Pond exposure appears to have been originally a bowldery till, the fragments of which in most cases have subsequently completely disintegrated. The disintegrated granitic material probably constitutes ninety or ninety-five per cent. of the mass, and is apparently of local origin since a knob of similar granite projects through the till a short distance to the north. There are a few pebbles of a fresher, though still distinctly weathered granite dispersed sparingly in the till. The difference in the extent of the decay is probably to be explained by the fact that the process which subsequently brought about disintegration were, in the larger portion of the material, well under way at the time of the ice advance, though actual disintegration may not have taken place until long afterwards. The fresher fragments were probably derived from portions of the ledges from which the more highly decomposed material had previously been removed. The thickness of the lower till as exposed in the gravel pit is about four or five feet. The color of the till is slightly darker than the overlying buff till, but the distinction is not marked.

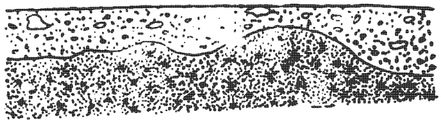
The upper till is composed of a heterogenous mass of material in which the same pink granite predominates, but with a considerable intermixture of foreign material. Its line of demarcation from the lower till is well defined, but, as would be expected from the fact that granite is the predominating material in both cases, is not so sharp as in the first two of the Brockton tills. All fragments of the upper till are fresh and usually present well glaciated surfaces.

PINE STREET EXPOSURE, STOUGHTON

The gravel pit in which was found the last of the tills to be described is located on the south side of Pine street at its junction with Pleasant street near the northern boundary of the town (Fig. 2, Exposure 5). The cut was about fifteen feet deep at the time it was seen by the writer. Two tills were distinctly exposed in the section, the relations of which are shown in Fig. 5.

The lower till, as in every case which has been described, is very homogeneous in composition. In this instance it is composed largely of the disintegrated material of a biotitic and hornblendic syenite, the source of which is probably close at hand. There is a slight admixture of foreign material but probably not more than 5 per cent. As in the case of the Ames

Pond exposure the till appears to have been originally composed largely of bowlders, the decay of which was well under way at the time of the laying down of the till, but which did not completely disintegrate until some time afterwards. Some of the larger bowlders still show undecomposed cores, but as a rule the disintegration is complete. The color is rather a dark brown, somewhat similar to the reddish-brown color of decomposed diabase, and serves to sharply separate the lower from the upper till.



Vertical and horizontal scale: 1 in. = 30 ft.

FIG. 5.— Section showing the relations of the older and younger tills in the Pine street exposure, Stoughton. (Exposure 5 of Fig. 2.)

The upper till is of the ordinary heterogeneous type abounding in foreign fragments, many of them rather far-traveled. There is proportionally little of the dark syenite in the upper till, differing in this respect from the Pearl street and Ames Pond exposures in which the predominating material of both tills is the same. When present in the upper till the syenite is fresh.

In the case of the Center street and Intervale Park exposures of Brockton the reasons have been given for regarding the tills as probably representing the earliest of the Pleistocene advances. One of the most prominent of these reasons, namely, the position of the till upon deeply decayed and unglaciated rock surfaces, cannot be applied with certainty to the last three tills described, since the immediately underlying rock is not exposed and its condition is not known. The difference in the colors is also a noticeable feature, the granite and syenite tills showing nothing of the high colors which characterize the tills derived from the conglomerate. A study of granites decayed *in situ*, however, shows that high colors are not the necessary accompaniment of disintegration such as the granite of the tills has undergone. The same close dependence of composition upon the underlying or immediately adjacent rock, the same small percentage of foreign material, the same highly weathered character, and the same distinct or even sharp division from the overlying tills, all seem to point to an origin similar, and probably contemporaneous with that of the Brockton tills. The deposition of the tills is believed to date from the time of earliest Pleistocene ice advance.

POSSIBLE INTERGLACIAL ROCK DISINTEGRATION

A further reason for considering the tills composed of highly oxidized or disintegrated material as representing the first ice invasion lies in the fact that the weathering is distinctly more advanced than in the exposures of what seems likely to prove to be examples of interglacial weathering. It has been seen that at the advent of the first ice sheet the rocks of the region were deeply decomposed as, for example, the conglomerate at Brockton. It is also known that where the conglomerate was so situated as to receive full benefit of the erosive action of the ice of the last advance the ledges are perfectly fresh. Between these two extremes there are numerous examples of a partial breaking up of the ledges by atmospheric agencies, and a partial disintegration. Such a case is illustrated in Fig. 6.

The moderate amount of decay exhibited by ledges of this class, as compared with ledges known to be pre-glacially decomposed, or with tills formed from such decomposed material, and the considerable amount which they show as compared with the freshly glaciated ledges of the last ice advance, seem to make a plausible case in favor of the view of interglacial weathering. In this case we have a rough measure of the time from the earliest of the Pleistocene ice advances to the present time, for both the field relations and weathered character show that the conditions mainly antedate the last of the ice invasions. The evidence of this weathering, if it be accepted as interglacial, is indicative of the great length of such time as compared with that which has elapsed since the final disappearance of the ice.

The preservation of these ledges evidently depended in many cases upon the character of the topography, but this is not always the case. The general explanation probably lies in the fact that all of the occurrences noted lie in the southern belt, in which, with the exception of the hills and other prominences, the work of the ice of the last invasion was largely one of deposition.

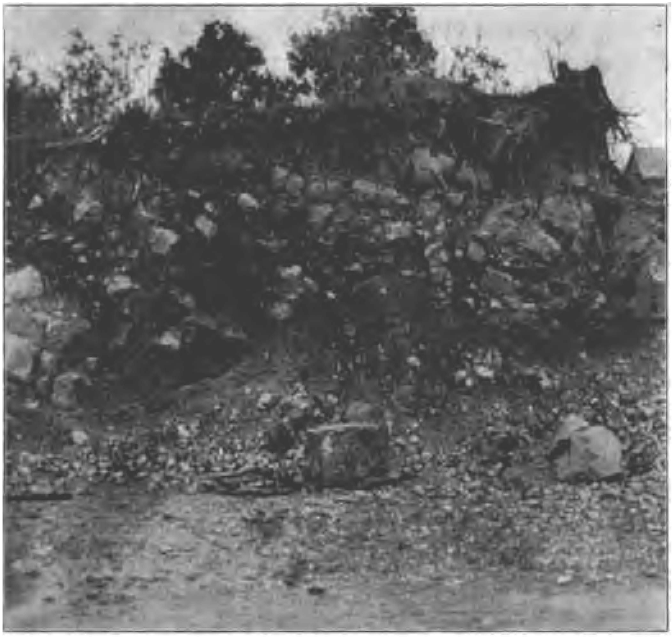


FIG. 6.—View of disintegrated ledge of conglomerate, Intervale Park, Brockton. The weathering is supposed to be interglacial in age.

SUMMARY AND CONCLUSIONS

1. The Pleistocene ice sheet on its first advance found a somewhat deeply decayed rock surface, many remnants of which are now to be seen.

2. The erosive power of the first advance was not sufficient to entirely remove the products of decay, for tills evidently composed of such products have been found by the writer beneath the ordinary tills of the region. These have been described in this paper.

3. The older tills are probably the result of the re-working of

pre-glacially decomposed rock and its accompanying soil, rather than by the process of accretion, by which many of the later deposits of till, such as drumlins, etc., were built up.

4. The remnants of the early till are characterized by (*a*) the presence of 20 per cent. or more of clay, (*b*) the presence in some of the tills of 10 per cent. or less of pebbles, (*c*) a composition which is dependent almost entirely upon the underlying or immediately adjacent rock, (*d*) the decayed or disintegrated character of its materials, (*e*) the presence of colors characteristic of high oxidation, (*f*) its position in certain cases upon deeply altered and practically unglaciated rock surfaces, and (*g*) its distinct line of demarcation, both as to color and composition, from the overlying till.

5. The upper till, on the other hand, is characterized in the region under discussion by (*a*) the presence of probably less than 5 per cent. of clay, (*b*) the presence of 40 to 50 per cent. of rock fragments, (*c*) a composition often largely independent of the immediately underlying rock and including numerous far-traveling erratics, (*d*) slight oxidation, and (*e*) by its unweathered and distinctly glaciated fragments.

6. No evidences of a soil zone between the two tills have so far been observed.

7. It seems probable that there were comparatively few localities in which the highly oxidized tills remained at the time of the last invasion, for otherwise there should be more traces of oxidized material, especially the colored clays, in the later till. The early tills were probably largely eroded during the later stages of the same ice sheet by which they were formed.

8. The action of the ice of the last advance in many cases was to cover the earlier till remnants by a new coating of till, and was protective rather than erosive in its nature.

9. Nothing indicative of more than two general periods of glaciation has been noted by the writer. The position of stratified deposits between two tills identical in character, and of the Wisconsin type, is probably to be explained as resulting from

the overriding of deposits laid down during a temporary retreat or local recession of the ice of the same general invasion.

10. The post-glacial weathering is in general confined to a slight oxidation of the till, the wearing of the pebbles, bowlders, and glaciated ledges being usually limited to a slight superficial decay or a mere discoloration of the surface.

11. There are numerous exposures showing rock disintegration of a type intermediate between the high decay characteristic of the pre-Pleistocene weathering and the slight weathering of post-glacial times. This disintegration is believed to have taken place largely in interglacial times.

MYRON L. FULLER.

U. S. GEOLOGICAL SURVEY,
Washington, D. C.

SKETCH OF THE GEOLOGY OF THE SALINAS VALLEY, CALIFORNIA[1]

In June and July 1900, under the direction of Dr. J. C. Branner, Mr. L. D. Mills and the writer undertook to trace out and map the formations in Monterey county, California, which appear to bear directly on the underground water supply of the Salinas Valley. During this and two subsequent trips to the same region the data were collected which form the basis of the present paper.

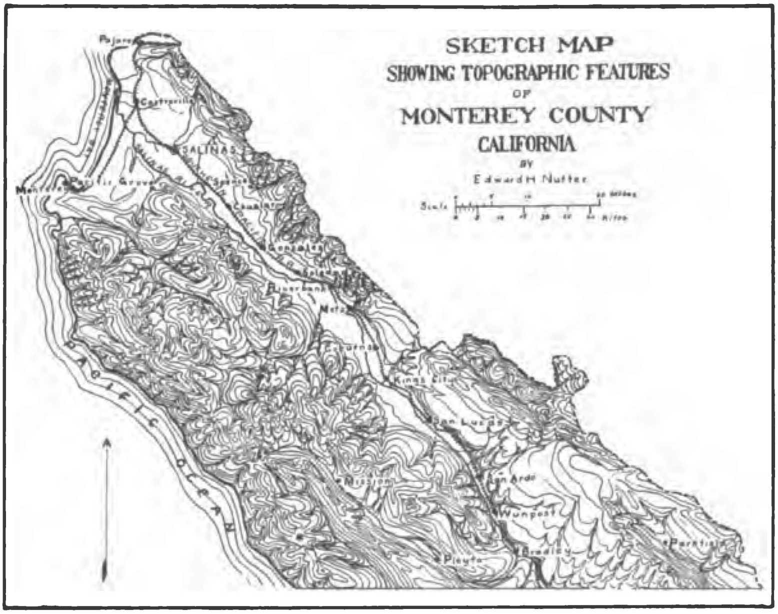
The Salinas Valley is a long, sword-shaped depression extending nearly southeast from Monterey Bay, to and across the southern end of Monterey county. The larger tributaries of the Salinas River run for a good part of their length in troughs parallel to the main valley, forming with it part of a remarkable series of valleys existing in the Coast Ranges of California, which for a distance of nearly five hundred miles are almost exactly parallel. In the Salinas Valley are evidences of a fault in the older rocks extending very persistently for several miles parallel to the main valley.

In its northern part, if not throughout its whole length, the Salinas Valley is cut in granite and other crystalline rocks, principal among which are biotite schists with crystalline limestone lying unconformably on them. The granite is intruded into the schists and is apparently the agent which metamorphosed the limestone. The granites, gneisses, and schists cover large areas while the limestone occurs only in patches. Of the crystalline rocks other than those mentioned there is one area of an eruptive that looks like andesite on top of the water-shed between Monterey and San Benito counties, northeast of the town of Salinas, and an area in the neighborhood of Metz containing a variety of intrusive and eruptive rocks in addition to several kinds of metamorphics. Hand specimens of these have been collected but have not yet been identified. There is also an extensive area of serpentine along the southeastern boundary of Monterey county.

---

[1] Published by permission of the director of the U. S. Geological Survey.

Since it was cut out the Salinas Valley has been filled with sediments of Tertiary and later age. If there are sediments older than the Miocene and newer than the metamorphics, they are not uncovered at any place visited, with the exception perhaps of a small area about the headwaters of the San Lorenzo River near the county line, where there are rocks resembling the Franciscan cherts. The Tertiary rocks are of Pliocene and Miocene ages, and these are separated by an unconformity.

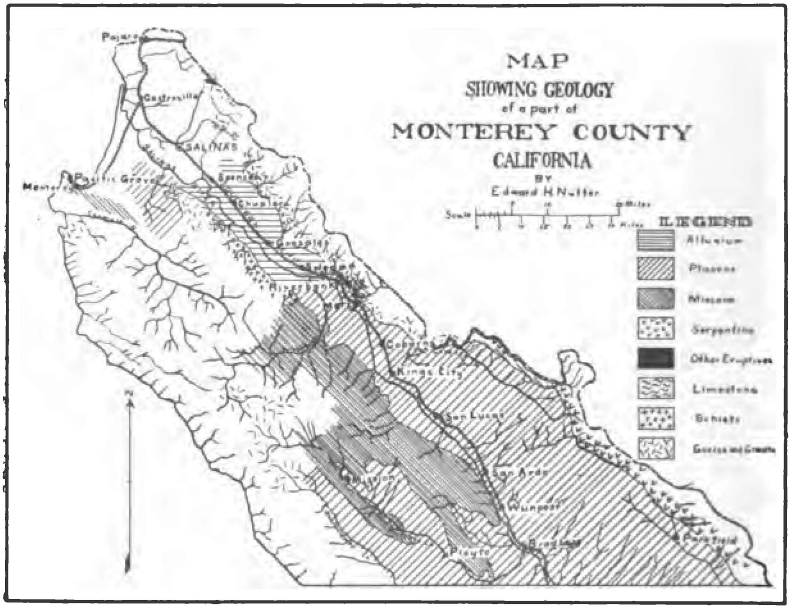


Southeast from the town of Salinas the valley narrows down from a broad rolling plain to a sloping floor about eight miles wide, bounded on each side by granite mountains. Southwest of Salinas, across the river, are highlands formed of Pliocene[1] sands and gravels, and deeply scored by ravines.

---

[1] The age of these beds was determined by Mr. Ralph Arnold, of Stanford University, from fossils collected by the writer fourteen miles east of Monterey, in the center of section 20, 16 south, 3 east.

From Spence's to a few miles southeast of Soledad the floor of the valley is covered by material washed in from the granite hills and mountains on either side. This alluvium or granite wash is very porous, and this has given rise to topographic features characteristic to this part of the valley. In the rainy season the water rushes out of the steep canyons bearing a heavy burden of sediments until it reaches the floor of the valley, where it sinks, leaving sand, gravel, mud and drift strewn around over the place where it disappeared. This has gone on until alluvial cones have been built up several miles wide and of considerable thickness. These alluvial cones or fans have themselves been cut by smaller gulches having steep sides and flat bottoms. A rudely stratified earthy conglomerate, the pebbles of which are angular fragments of granite, schist and gneiss, varying in size from sand grains to pieces the size of one's head, is usually found capping these fans.



It seems probable that both Pliocene and Miocene sediments underlie the alluvium, for they occur at the northwestern end of this area and dip under it at the southeastern end below Soledad. In addition to this, there is a point of granite projecting through one of the alluvial fans about two and one half miles east of Gonzales in 16 south, 3 east, section 14, southeast quarter. The top of this granite exposure is capped with shale that has all the appearance of the diatomaceous Miocene shale. It seems probable that the structure of this region is that shown in the accompanying section (Fig. 1).

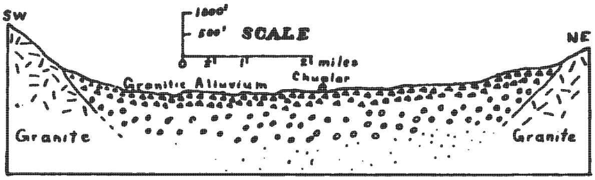


FIG. 1.—Ideal section across the Salinas Valley showing its probable structure at Chualar.

Beginning near Riverbank on the east, and at a point about six miles southwest of Soledad, on the west, water-worn gravels of Pliocene age begin to crop out from beneath the granitic talus, and gradually rise and form a terrace that extends eastward for about eighteen miles from Kings City to a series of anticlinal valleys which form the eastern boundary of the terrace or plateau.

Serpentine is abundant along the eastern edge of the terrace, though whether or not it forms a continuous sheet as indicated by the accompanying sketch map is not now known, for the parting was not followed continuously, but was visited only at such places as the roads permitted. At these points serpentine was found underlying the Pliocene plateau. The edge of contact between the Pliocene beds and the underlying serpentines

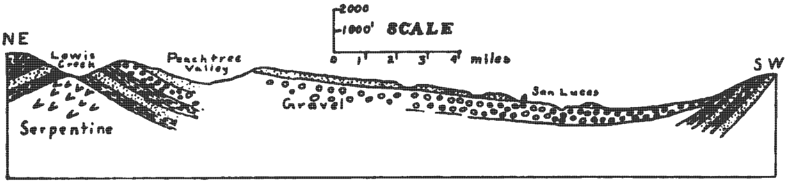


FIG. 2.—Structure of the Salinas Valley and adjoining plateau along a northeast-southwest line through San Lucas.

reaches an elevation of nearly two thousand feet above Kings City from near Parkfield northwest to a point fifteen miles east of Kings City.

The structure of the country between Kings City and the alluvium covered district is shown by (Fig. 3) a section through Metz.

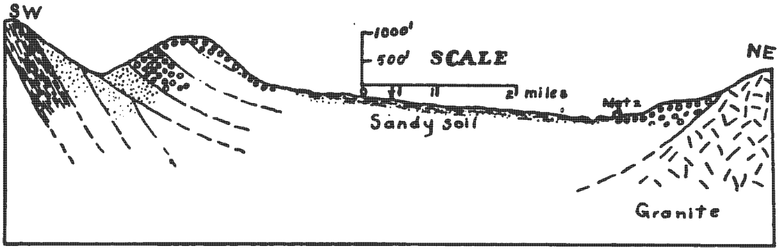


FIG. 3.—Structure of the Salinas Valley along a northeast-southwest line through Metz.

From Kings City to the San Luis Obispo county line the Pliocene beds form the eastern escarpment of the immediate valley with an average height of about one hundred feet above the river. The lower beds extend entirely under the valley, thereby making the terrace area or plateau tributary to its underground water supply.

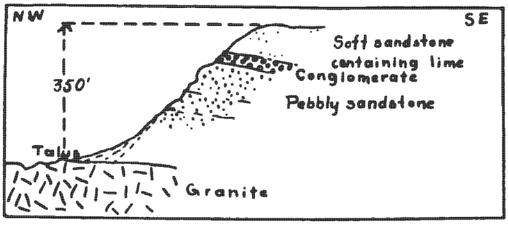


FIG. 4.—Croppings of terrace beds five miles northeast of Kings City at the head of the Salinas Valley Water Company's ditch, on the San Lorenzo River.

For the most part the Pliocene beds overlie the Miocene, but in some places they lie directly on the older rocks (Fig. 4).

In the southern part of Monterey county there have been at least two elevations of the land since the deposition of the Miocene beds, for the Pliocene gravels forming the large plateau are to a great extent composed of shale pebbles, and these same pebble beds have been tilted along with the underlying beds of shale. In places the Pliocene and Miocene may be conformable.

This seemed to be the case near the southernmost point of the Miocene area shown on the accompanying geological sketch map. Here the gravels and sands rest on the sandstones and shales and have apparently the same dip and strike. For the most part, however, along the parting between the Pliocene and the Miocene, there is such a marked difference in the dip of the two series on either side of the contact, as to make almost certain an erosion line between them.

The Miocene shales and sandstones are much contorted, and are characterized by steep dips, sometimes vertical. The Pliocene sands and gravels[1] have much gentler dips and are also persistently characterized by having a capping of soft limy sandstone.

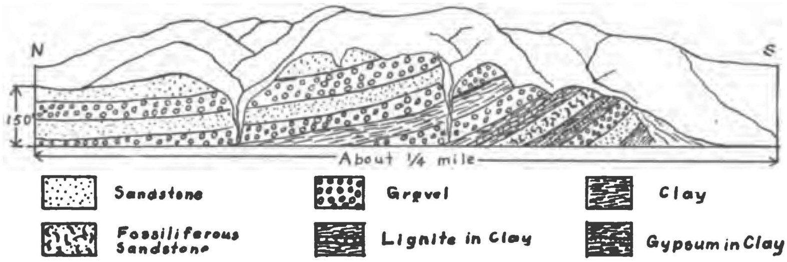


FIG. 5.—Terrace beds exposed in a railway cut three miles northwest of Bradley.

The ranges of hills lying between the Nacimiento and San Antonio creeks, and the San Antonio Creek and the Salinas River are made up almost entirely of Miocene sandstones and shales; while the valleys of the Nacimiento and San Antonio are filled with the Pliocene sands and gravels.

There is much granite and gneiss in the region drained by the head waters of the Arroyo Seco, the San Antonio, and the Nacimiento, as the beds of these streams are filled with pebbles and bowlders made up of these rocks.

[1] The age of this Pliocene area was determined by fossils collected in a railway cut three miles northwest of Bradley. The Miocene fossils are from shale beds outcropping on the southwest bank of the Salinas River at Wunpost. They were all identified by Mr. Ralph Arnold.

RECAPITULATION

The Salinas Valley in Monterey county is a trough that probably holds a great deal of water. In its northern part from near Riverbank to some point between Chualar and Salinas it is covered with talus washed in from the mountains.

Pliocene and Miocene sediments underlie this talus though to what extent is uncertain. Going southward the Pliocene beds rise from beneath the talus at about Riverbank; and from east of Kings City, to the southward, they form an extensive plateau which continues into San Luis Obispo county and is probably tributary to the underground water supply of the Salinas Valley.

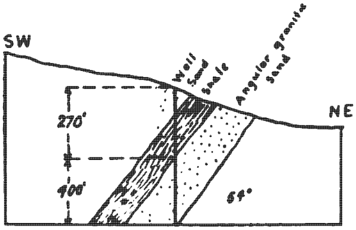


FIG. 6.— Sand and shale beds at Barrett's oil well, four miles northwest of Parkfield. Water was encountered at two levels in the angular granitic sand. The elevation of the mouth of the well is 1800 feet above Kings City.

In the drainage area of the San Antonio and Nacimiento creeks there are also Pliocene gravels which are indirectly tributary to the underground water supply of the Salinas Valley.

It seems probable that deep wells put down near the western margin of the Pliocene terrace between San Lucas and the San Luis Obispo county line may yield considerable water, perhaps artesian.

Slightly salty water has been found in wells in the terrace beds above the valley, though there are folds lying between these bore holes and the valley (Fig. 6).

It is possible that artesian water may be found in the region of the San Antonio and Nacimiento creeks, but not enough detailed work has been done there to warrant any definite conclusions upon the subject at present.

EDWARD HOIT NUTTER.

STANFORD UNIVERSITY.

NOTES ON THE FOSSILS FROM THE KANSAS-OKLAHOMA RED-BEDS

THE age of the series of rocks lying conformably on the Permian and unconformably below the Comanche Cretaceous in Kansas and Oklahoma has for a number of years been considered problematic. The earlier Kansas geologists classified these formations anywhere between the Carboniferous and the Middle Cretaceous. Later investigators have agreed that the series is not older than the Permian, nor more recent than the Jurassic. In Texas, rocks which appear to be of the same age are assigned to the Permian on the authority of such paleontologists as Cope and White.[1]

In the absence of certain determination as to age, the general term Red-beds has been applied to these formations in Kansas and Oklahoma. The term refers to the lithological appearance of the rocks. Blood red sandstones, clays, and shales make up the greater part of the thickness of the series. The shales are frequently strongly impregnated with mineral salts, of which gypsum and common salt form the larger part, although borax, magnesia, and others are not infrequent. These salts impart to the water of a great part of the area a characteristic taste, often rendering it unfit for use. In the central part of the Red-beds areas several ledges of massive gypsum occur. These ledges outcropping to the east form the escarpments and caps of the noted Gypsum hills which extend south from southern Kansas to the Wichita Mountains, and thence into central Texas. Ledges of dolomite and highly saliferous shales are found in many horizons of the Red-beds.

There is not lacking literature on the Red-beds. Some of the most noted geologists and paleontologists of America have written concerning these rocks. Such men as Cope, Hill, Williston, Haworth, Hay, Vaughan, Ward, Beede, Stevenson, and others have contributed to our knowledge of the subject. The most comprehensive articles, however, are by Prosser and Cragin. Professor Cragin, in addition to incidental mention of the Red-beds in numerous papers on the geology of southern Kansas, has written two articles dealing exclusively with these series of rocks. In the first paper, entitled "The Permian Series in Kansas,"[1] the Red-beds are classified as Upper Permian, and are included under the Cimarron series, which is divided into two divisions, the Salt Fork and Kiger. Each of these divisions is further subdivided on purely lithological grounds into five formations. Professor Cragin's second paper, "Observations on the Cimarron Series,"[2] is little more than a revision of the former one. The grouping of formations and sub-formations is slightly changed, and a few new points added. These two papers contain the best description of the Red-beds extant. Professor Prosser's paper on "The Cimarron Series, or the Red-Beds,"[3] contains the best historical review of the literature of the subject so far published, as well as an excellent description of the Kansas Red-beds.

---

[1] Second Annual Report Geological Survey of Texas, 1890, pp. 415-419.

The reasons for assigning the Kansas-Oklahoma Red-beds to the Permian were chiefly two, viz., first, these rocks were considered to be of the same age as the Texas Red-beds, which are recognized as Permian; and, second, the series grades conformably upward from rocks of undoubted Permian age. The fact that so far as known not a single fossil has been found in the Kansas Red-beds has always been the great obstacle to the accurate correlation of the series. During the past two years, however, as the result of both private investigation and of the work of the Oklahoma geological survey at least four localities have been discovered in the Oklahoma Red-beds from which fossils have been identified. These localities, with the character of the fossils contained in them, are as follows:

1. McCann's quarry, five miles southeast of Nardin, Kay county; vertebrates, invertebrates, and leaves.

---

[1] Colorado College Studies, March 1896, Vol. VI, pp. 1–48.

[2] American Geologist, May 1897, Vol. XIX, No. 5, pp. 351–363.

[3] University Geological Survey of Kansas, 1897, Vol. II, pp. 75–95.

2. Two miles northeast of Orlando, numerous vertebrates.

3. Cedar Hill and Bitter Creek, northeast of Watoňga; invertebrates.

4. Whitehorse Spring, sixteen miles west of Alva; numerous invertebrates.

Of these localities those numbered 1 and 2 are from the lower part of the Red-beds, not far from the base of the Harper sandstone. The fossils from locality numbered 3 were taken from ledges of sandy dolomite immediately beneath the heavy ledges of gypsum found near the middle of the Red-beds. Locality numbered 4 is from the Red Bluff sandstone in the upper part of the series.

A large vertebrate from McCann's quarry, or locality 1, was identified by Dr. S. W. Williston as *Eryops megacephalous* Cope, a form characteristic of the Permian of Texas. The invertebrates from the same locality were sent to T. Rupert Jones, who classified them as *Estheria minuta*, a Triassic form. The plants were shown to Dr. Lester F. Ward, who said that the forms seemed to resemble Mesozoic rather than Paleozoic types. From the Orlando locality Dr. Williston has identified the following forms: *Diplocaulus magnicornis* Cope; *Diadectidæ* Gen. indt.; *Pariotichus incisivorus* (?) Cope; *Labyrinthodont;* and *Trimerorhachis;* all of which he recognizes as Permian forms. From the locality numbered 3 but one species has been found. This is an invertebrate which here occurs in great numbers, and has been referred by Dr. J. W. Beede with some doubt to the Permian form *Sedgwickia*. The Whitehorse locality has yielded some twenty species of invertebrates, several of which are of new forms.

This locality is from the upper part of the Red-beds, or to be more exact from Cragin's Red Bluff sandstone perhaps 150 feet above the Medicine Lodge gypsum. The following genera are represented: *Conocardium*, *Aviculopecten*, *Schizodus*, *Pleurophorus*, *Bakevalia*, *Naticipsis*, *Pleurotomaria*, *Orthonema* and *Murchisonia*. One form that was at first thought to be *Jagmayeria*, a shell of Triassic age, has since been identified as *Dielasma*, very like *D. biplex* described by Waagen from the Permo-Carboniferous of India.

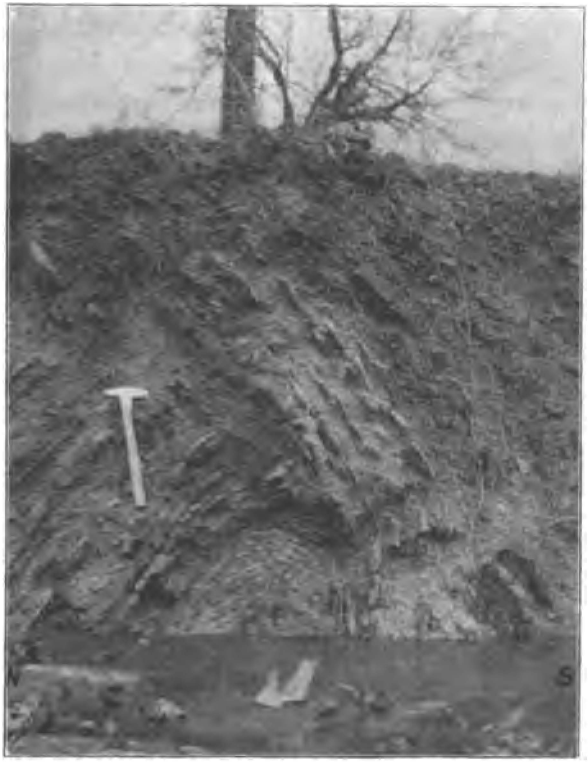
Unfortunately no Cephalapods have as yet been found in the locality and until this is done the question of the exact age of the beds may scarcely be decided. The facts at command lead to the inference that the Whitehorse Springs locality is well up toward the close of the Paleozoic

Charles Newton Gould.

The University of Oklahoma,
Norman, Oklahoma.

ILLUSTRATED NOTE ON A MINIATURE OVERTHRUST FAULT AND ANTICLINE

THE figure below represents a miniature anticline passing into a reversed fault above. It is on the Ozark-St. Paul road, on the east side of the road, one mile north of the town of Ozark, Ark. The rocks are of the Coal-measure series, and consist of shale interbedded with thin layers of sandstone. The strike of the fold is about east and west, it being one of the series of feeble folds on the northern border of the Ouachita folded area and near the southern base of the Boston Mountains.



The length of that part of the flexure which is visible, and which at the time the photograph was taken had recently been freshly exposed in working the road, is ten feet, and the height five feet.

Aside from the interest which attaches to this as an example of an overthrust fault passing into an anticline below, it bears strong evidence of very recent tangential pressure having been brought to bear upon the rocks of the region; for it is inconceivable that so small a flexure should break and produce a fault with many feet of superimposed rock to be broken through. The point is sufficiently elevated to suffer from slight erosion, and as the rock is mainly shale and easily eroded, the very few feet that have been removed since the faulting occurred could not represent much time, as the geologist reckons time.

A. H. PURDUE.

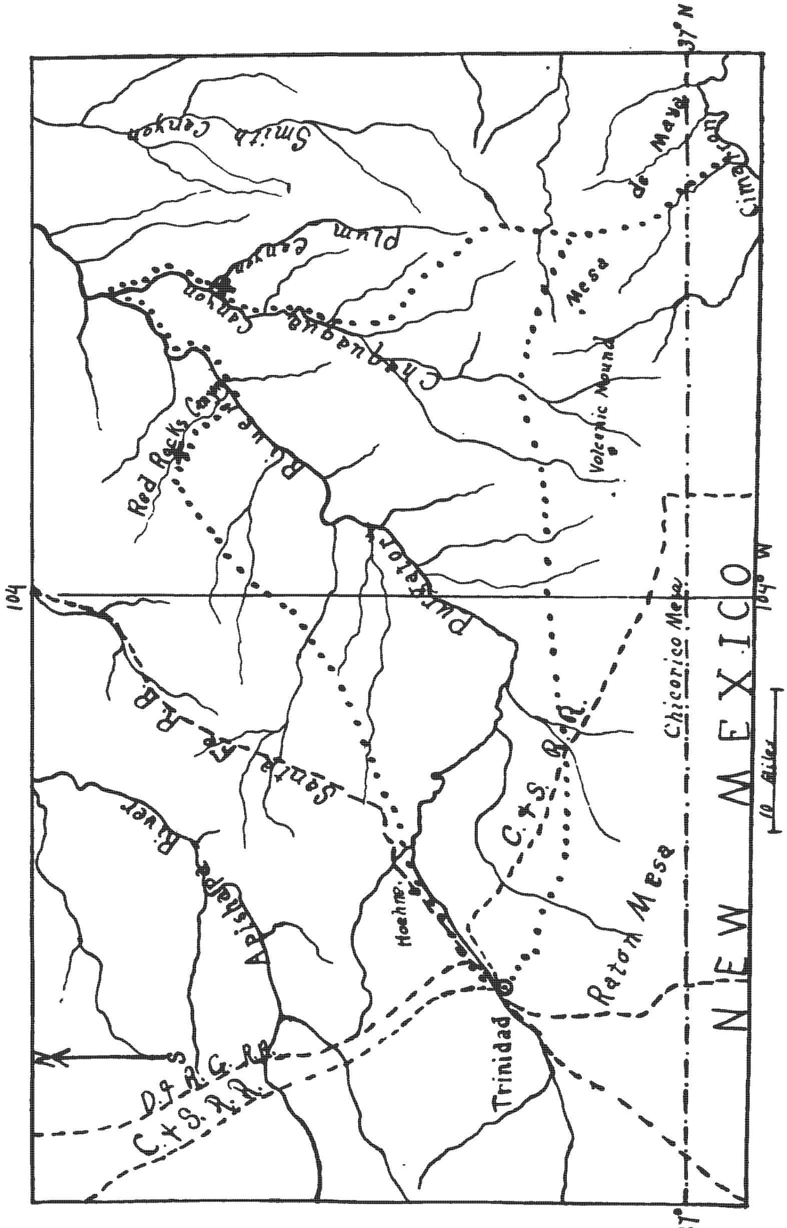
UNIVERSITY OF ARKANSAS,
Fayetteville, Ark.

THE MORRISON FORMATION OF SOUTHEASTERN COLORADO

A considerable part of southeastern Colorado and northeastern New Mexico is elevated to a height of about 5000 feet above sea level. The streams of this region have cut canyons to the depth of 700 feet or more. The most notable of these is the canyon of the Cimarron in New Mexico, and that of the Purgatory, or Las Animas, in Colorado. The studies of which the conclusions are given in this paper, were carried on mainly in the canyon of the Purgatory and its tributaries, although a side trip was made to the canyon of the Cimarron. The region examined is shown in the accompanying sketch map (Fig. 1). The canyon walls are steep and bare and complete sections are easily obtainable. The lower half is red sandstone overlain with gypsum (the "Red Beds"); the surface rock is also sandstone (Dakota.) Between this upper sandstone and the gypsum is the shale formation of which I specially write. The shales are found throughout the region examined wherever the streams have cut through the upper sandstone.

Two detailed sections were taken at the points indicated on the map by a cross (×), section 1, at the junction of Plum and Chaquaqua canyons, and section 2, in Red Rocks Canyon. Since the canyons do not cut entirely through the Red Beds at any point within the area examined, it is impossible to accurately estimate their full thickness; the sections, therefore, represent only the upper part of these beds.

For some distance above the bottom of Plum Canyon (section 1) the rock is evenly stratified, ripple-marked and somewhat shaly. A limestone layer four feet thick near the bottom extends uninterruptedly for many miles and forms a convenient line of reference. Above these evenly stratified beds occurs a series of massive layers of coarse red sandstone aggregating about 250 feet in thickness. This series forms the steepest and


37° N
Smith Canyon
Plum Canyon
Mesa de Maya
Cimarron
Mesa
Chaquaqua Canyon
Volcanic Mound
Red Rocks Canyon
Purgatoire
104
104° W
Santa Fe R.R.
C. & S. R.R.
Chicorico Mesa
Apishapa River
Hoehne
Raton Mesa
NEW MEXICO
10 Miles
Trinidad
D. & R.G. R.R.
C. & S. R.R.
37°

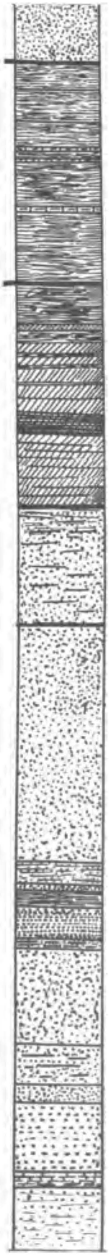
most conspicuous part of the canyon walls. It is notably cross-bedded and the frequent changes in the direction of bedding, as well as the frequent truncations of the cross-bedded layers, is indicative of deposition by shifting currents. The upper part of the massive series is slightly calcareous and oölitic, the little spheres of which, about one millimeter in diameter, are harder than the matrix in which they are set, and the weathered surface is thus given a "bird's-eye" appearance. The oölitic beds pass gradually upward into gypsiferous shales and thence into solid gypsum without any indication of stratigraphic break or lapse of time. No trace of fossils of any kind was found in the Red Beds.

The upper sandstone forms the general surface of the country over wide areas. The Cretaceous formations from the Ft. Pierre to the Dakota are traversed in passing eastward from Trinidad across the El Moro quadrangle which has been described by R. C. Hills,[1] and the Dakota, may be traced onward thence over the whole region studied. The Dakota is composed mainly of sandstones, although shales occur in it in places. About 150 feet from the base occurs a steel-blue shale (probably fire-clay), 2 to 6 feet thick were examined. Above this clay the formation is somewhat evenly bedded, ripple-marked and in certain places contains numerous impressions of dicotyledonous leaves. In a few places small pebbles were found near the base. The largest of these were about one fourth inch in diameter. The pebbles are so few in number that the strata containing them can scarcely be described as conglomeratic.

Between the Dakota and the gypsum at the top of the Red Beds lies the shale formation under consideration. It is constant in occurrence, although the thickness varies from place to place. At the mouth of Plum Canyon the thickness is 85 feet; in Red Rocks Canyon, it is 132 feet. In Chaquaqua Canyon, ten miles from the mouth of Plum Canyon, it is 175 feet (by barometer). The formation is composed mainly of variegated clay-shales of the variety known as "joint clay." A subordinate amount of

---

[1] U. S. Geol. Surv., El Moro Folio, Colo.



140 feet. Dakota. Two massive sandstone layers separated by a soft shaly layer of varying thickness; leaf impressions near the top of the upper division.

11 feet Greenwich clay shale, soft and fine grained.

12 feet dull red clay shale, soft and fine grained.
10 feet brown to yellow shale.
6 inches argillaceous limestone; numerous fine dark laminæ.
18 inches buff-colored shale.
6 inches argillaceous limestone; numerous fine dark laminæ.
18 feet variegated joint clay.

2 feet argillaceous limestone, fine grained and hard, with contorted laminæ.

30 feet variegated shales; very soft and easily eroded.

15 feet dark shales containing irregular masses of gypsum.
18 inches gypsum containing streaks of clay.
8 feet variegated shale containing nodular-like masses of gypsum which vary in size from grains to masses a foot or more in diameter. About one third of the mass is gypsum.

25 feet gypsum in well-defined layers. Often separated by layers of clay.

5 feet massive gypsum.

30 to 40 feet red gypsiferous shales, soft and regularly bedded.

60 feet red calcareous sandstone, oölitic, cross-bedded. Individual layers variable in thickness and character. Near the top it becomes shaly and passes gradually into the gypsiferous shales above.

175 to 200 feet red sandstone, massive, cross-bedded.

6 feet red arenaceous shale.
1 foot red sandstone.
4 feet fine red shale.
9 feet even-bedded red sandstone.
2 feet red arenaceous shale.

40 feet red sandstone, cross-bedded; the individual layers thin out laterally.

15 feet poorly cemented red sandstone alternating with layers of shale.

5 feet massive red sandstone.

30 feet soft red sandstone containing hard layers which are ripple-marked.

4 feet hard, white, argillaceous limestone composed of numerous thin layers; greatly [contorted.

15 feet red sandstone in thin flaky layers.

(River bottom.)

FIG. 2.—Section 1, near the mouth of Plum Canyon.

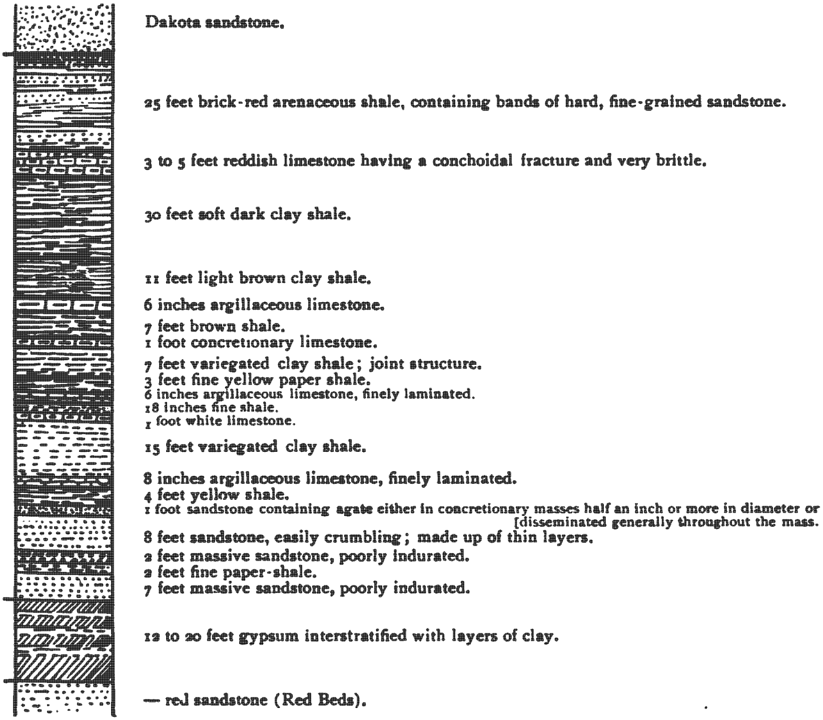

Dakota sandstone.
25 feet brick-red arenaceous shale, containing bands of hard, fine-grained sandstone.
3 to 5 feet reddish limestone having a conchoidal fracture and very brittle.
30 feet soft dark clay shale.
11 feet light brown clay shale.
6 inches argillaceous limestone.
7 feet brown shale.
1 foot concretionary limestone.
7 feet variegated clay shale; joint structure.
3 feet fine yellow paper shale.
6 inches argillaceous limestone, finely laminated.
18 inches fine shale.
1 foot white limestone.
15 feet variegated clay shale.
8 inches argillaceous limestone, finely laminated.
4 feet yellow shale.
1 foot sandstone containing agate either in concretionary masses half an inch or more in diameter or [disseminated generally throughout the mass.
8 feet sandstone, easily crumbling; made up of thin layers.
2 feet massive sandstone, poorly indurated.
2 feet fine paper-shale.
7 feet massive sandstone, poorly indurated.
12 to 20 feet gypsum interstratified with layers of clay.
— red sandstone (Red Beds).

FIG. 3.—Section 2, in Red Rocks Canyon.

sandstone occurs in places but there seems to be no particular horizon at which this is likely to be found. In Red Rocks Canyon it occurs at the base; in Plum Canyon, none is found; in a side gulch east of Plum Canyon a brecciated layer occurs near the top containing angular fragments one quarter inch in diameter; in Chaquaqua Canyon, four miles from the mouth of Plum Creek, a coarse cross-bedded sandstone layer 15 feet in thickness occurs about 50 feet from the top; just across the canyon from this point, perhaps two miles distant, and at the same horizon, about 30 feet of limestone is found in place of the sandstone. In many places the sandstones are friable and composed of nearly pure quartz. The sand is used as a flux in assaying where pure silica is required. The occurrence of the limestones, most of which are more or less argillaceous, is as eratic as that of the sandstones. The relative amount and position of sandstones, shale and limestones at any one point is no indication that a similar relation will be found at any other point. There is no abrupt lateral change, but the various beds blend into each other or pinch out laterally in a gradual though somewhat rapid manner, so that, while no sudden change is seen, a comparison of sections a few miles apart may show a total change in kind and relation of materials. The Dinosaur bones to be described later were found in the shales at nearly every horizon. Aside from these, no fossils were found. Careful search at every horizon failed to reveal a single invertebrate.

The three formations—the Red Beds, the shales, and the Dakota sandstone—are apparently conformable. There seems, however, to be some indication of a break between the gypsum and the shales, and still more between the shales and the Dakota sandstone. The red sandstone, as already pointed out, passes upward through shales into the gypsum by a gradual transition. There was no evidence found, at any of the places examined in detail, of a break in deposition between the red rocks and the gypsum. At the top of the gypsum the evidence is not so satisfactory in every case. In Red Rocks Canyon the change is abrupt from gypsum to sandstone; but in Plum Canyon and elsewhere the upper layer of the gypsum beds is shale containing irregular masses of gypsum. This is overlain by the variegated shales. The gypsum beds vary in thickness from 20 to something like 100 feet. In some places, at least, as shown in the sections given in this paper, the shales increase in thickness as the gypsum decreases, and vice versa. It is possible, therefore, that the gypsum beds were exposed and slightly eroded previous to the deposition of the shales. However this may be, it seems clear that the gypsum belongs to the Red Beds series, and probably marks the closing stage of the Red Beds period. If this interpretation be correct, there is no gypsum in any part of the shale formation of southeastern Colorado, so far as known. The contact of the shales with the Dakota sandstone is more plainly marked, and in places exhibits gentle undulations, which appear to be due to erosion of the shales previous to the deposition of the Dakota.

Vertebrate fossils were found in the shales near the mouth of Plum Canyon in a number of places. No means were at hand for digging deep enough to obtain good material, but many fragments were found on and near the surface. Two of the best preserved fragments—the centrum of a vertebra and the portion of a femur—are shown in the photograph, Fig. 4, about one eighth natural size. The dimensions of the vertebra are as follows:

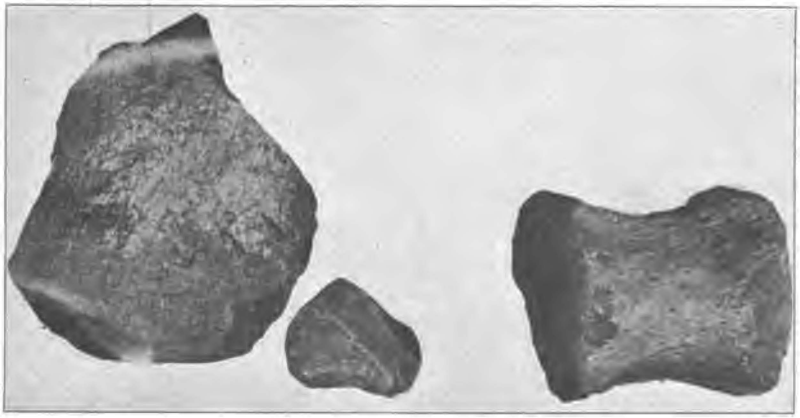


FIG. 4.

Length - - - - - -	8	inches
Transverse diameter at ends - -	7	"
Depth at ends - - - - -	8	"
Transverse diameter at center - -	5¼	"
Depth at center - - - - -	6½	"
Depth of sockets, each - - -	½	"

The fragment of the femur is 13 inches long, 12 inches wide, and 7 inches in diameter. This does not represent the thickness of the complete bone, since one side is imperfect. These bones are solid and coarse in texture. One hollow bone was also found. The piece is about 5 inches in diameter and 7 inches long, with a hollow 2 inches in diameter. The material obtained is not sufficient for generic determination, but in size, texture, and general aspect the bones are similar to the Dinosaurian remains of the Atlantosaurus Beds of central Colorado and Wyoming.[1]

That portion of the general section for the Rocky Mountain region which is useful for present comparison is as follows: The Red Beds formation (the so-called Jura-Trias) is overlain by the Morrison formation, or Atlantosaurus Beds. The line of demarcation is drawn at the top of the gypsum beds which occur in several localities along the mountains at the summit of the Red Beds. The gypsum is regarded as marking the closing stage of the Red Beds period. The Morrison formation, which averages about 200 feet in thickness, is composed principally of variegated shales. These contain sandstones and impure limestones, the thickness and relative position of which vary from place to place, or may be entirely wanting. It is this formation which is noted for its huge Dinosaurs. Above the Morrison occurs the Dakota sandstone. It should be borne in mind that only the middle one of these three formations, the Morrison, contains Dinosaurian remains.

Since the vertebrate fossils of southeastern Colorado have not been studied, and since they are the only known fossils from the shale formation of that region, we must resort to other means of determining the age of the shales, and these will be chiefly stratigraphical and lithological, to which may be added such general paleontological evidence as may be drawn from unidentified bones.

a. As stated in a previous paragraph, the upper sandstone of the region in question was traced from a known area, and there can be little doubt, therefore, that it is Dakota. The Red Beds are in structure, color, and general aspect similar to the Red Beds of the mountain region, seventy-five miles to the west. They differ only in being composed of finer material and in being massive near the top instead of evenly stratified, as is often the case in the typical Red Beds along the mountains. The stratigraphic position of the shale formation is between the Dakota and the Red Beds. In this respect its position is identical with that of the Morrison.

---

[1] Since writing this article my companion, Mr. T. A. Pierce, has again visited the bone beds and found a number of new localities where bones occur in considerable numbers. The width of the territory in which these remains are found and their number indicate that this region would yield rich rewards to the bone hunter.

b. In lithological character, the shale closely resembles the Morrison, which, in its typical areas[1], is composed of soft, variegated clay, containing more or less sandstone and limestone. A comparison of the shale formation with the typical Morrison of Colorado shows a striking resemblance. There is a somewhat greater proportion of clay than in the Morrison, as would naturally be expected so far from the mountain area, which was probably a part of the feeding ground at that time. A comparison of the Morrison (Como) of Wyoming reveals a still closer resemblance, if, indeed, it cannot be called identity. One who is familiar with the Morrison and has studied the shales of southeastern Colorado finds a striking likeness between the two in material structure and general aspect.

c. The Morrison is notable chiefly for the great Dinosaurs found in its beds, and they are not found in the Dakota above nor in the Red Beds beneath. The bones found in the shales near Plum Canyon are similar in size, texture, and general aspect to the characteristic Dinosaurs of the Morrison formation. Although none of these bones have yet been studied by a paleontologist, there is little doubt that they are Dinosaur bones, and if Dinosaurs occur between the Dakota and the Red Beds, the presumption is that the formation containing them is an equivalent of the Morrison.

The shales found in the Canyon of the Cimarron perhaps deserve separate discussion. Near the southern boundary of Colorado is the divide between the Cimarron and Purgatory rivers. On this divide, a distance of nearly thirty miles, no stream, so far as observed, cuts through the Dakota. At the top of this divide is an extensive mesa capped by flows of basalt and known as Mesa de Maya. It is a part of the volcanic region extending from the mountains eastward along the southern border of Colorado. This mesa is separated from the equally elevated region of northern New Mexico by the canyon of the Cimarron, which is cut not only through the basalt and the Dakota, but deep into the Red Beds. Here, as further north, a shale formation lies between the Red Beds and the Dakota. At the one point studied gypsum occurs near the top of the Red Beds, but a thick stratum of red sandstone lies between it and the overlying shales. The shales correspond closely in character and general appearance with those further north, although they are more arenaceous and thicker (about 350 feet). No fossils of any kind were found, but enough was seen of the formation to warrant the inference that it is probably the same as the formation which occurs in the same position in the canyon of the Purgatory, thirty miles further north, viz., the Morrison.

---

[1] See U. S. Geol. Surv., Monograph XXVII, Geology of the Denver Basin, p. 52; also W. N. LOGAN, Kas. Univ. Quarterly, 1900—"The Stratigraphy and Invertebrate Faunas of the Jurassic Formation in the Freeze-Out Hills of Wyoming," pp. 113-115.

SUMMARY

1. From the foregoing considerations it appears that the stratigraphic, lithologic, and paleontologic evidence all point to the inference that the shales of southeastern Colorado are of Morrison age. It is inferred, furthermore, that this formation extends from its line of outcrop along the flank of the Front Range, underneath the Dakota, as far east as Smith Canyon,* about seventy-five miles, and as far south as the canyon of the Cimarron. How much further it extends in these directions is not determined.

2. Although there are gypsiferous shales lying between the gypsum and the fossiliferous shales, which might seem at first thought to form a transition, it is thought that the line of demarcation should be drawn at the top of the gypsiferous shales. If this division be correct, there is no gypsum in the Morrison formation of southeastern Colorado. In this it differs from that formation as reported from some localities. The gypsum is here considered as belonging to the closing stage of the Red Beds period.

WILLIS T. LEE.

TRINIDAD, COLO.

EDITORIAL

THE JOURNAL has had occasion to comment with some severity on the action of certain former officials of the state of Missouri relative to the official geological investigations of that state. It is therefore with the greatest pleasure that it now makes note of the recent appointment of a new Board of Managers of the Bureau of Geology and Mines, by Governor A. M. Dockery. The following gentlemen have been elected officers of the Board: President, Professor E. M. Shepard, Springfield, Mo.; Vice President, Dr. E. B. Craighead; Secretary, Colonel H. H. Gregg, Joplin, Mo.; Dr. W. S. Allee, Olean, Mo. The headquarters of the survey have been removed to the School of Mines at Rolla, under orders from the legislature. A state geologist will soon be appointed.

REVIEWS.

Department of Geology and Natural Resources of Indiana, Twenty-fifth Annual Report. By W. S. BLATCHLEY, State Geologist, Indianapolis, Ind., 1900. Pp. 782. Maps and plates.

The current report deals mainly with the cement resources of the state. It opens with a short paper by the state geologist on Portland cement, a compilation treating of its history, uses, composition, process of manufacture, methods of testing, etc., together with a short history of the development of the industry in Indiana.

The report on the Lakes and Marl Deposits of Northern Indiana is the result of the joint work of the state geologist and and Dr. George H. Ashley. It is a thorough report of some three hundred pages and is accompanied by seventy maps of individual lakes on which the marl deposits in their varying conditions of occurrence are represented by conventional signs. In the body of the text, full physiographic descriptions of the lakes are given, as well as the detailed economic geology of the marl deposits. The notes on the natural history of these lakes, which are appended to the descriptions, are of much interest to the student of botanical ecology.

It is found that a deposit of marl of a thickness of ten feet and covering 160 acres will supply a factory of 500 barrels daily capacity for 30 years. Such a supply is termed a "workable deposit" in the report. There are thirty-two lakes which have at least that much marl available. With improved methods of raising marl from deeper waters, the productive area of these lakes will be much enlarged, and there will be added to the number half as many more, whose deposits are for the most part under water of greater depth than ten feet, the present limit of accessibility.

In regard to the origin of the marl the authors do not attribute more than 1 per cent. to shells as a source. The immediate source they believe to lie in the calcareous matter of the glacial clays which reaches the lakes in the form of the soluble double carbonate, $CaH_2(CO_3)_2$. This is believed to be carried by subterranean rather than superficial streams, because the marl deposits are found in association with sub-lacustrine springs, while the mouths of streams and the currents leading away from them are marked by deposits of muck and silt. Calcium carbonate ($CaCO_3$) will be deposited if by any means CO_2 be withdrawn from the double carbonate. The authors recognize three such means.

1. Increase in temperature from mingling with the warmer lake waters.
2. Decrease in pressure as the spring water rises to the surface.
3. Extraction by aquatic plants, such as stoneworts, etc.

Since more than half the marl lakes do not have the stoneworts in abundance, and since the marl in general does not show that large percentage of organic matter which is shown by marls deposited through the agency of the stoneworts, the authors are inclined to minimize the part of aquatic plants.

As the spring water is colder than the lake water and denser owing to the carbonate in solution, we can see no cause for the rise of the spring water, except diffusion, in which the CO_2 released by ascending waters would be just balanced by that taken into solution by the descending currents.

If the main dependence is to be put upon the first means for removing the CO_2, *i. e.*, increase of temperature, it seems to us that springs which emerge superficially in the neighborhood of the marl lakes would have their waters warmed more rapidly than sub-lacustrine springs, and should thus have copious deposits of marl. No reference is made to such deposits. We believe a competent theory for the deposition of the marls is yet to be found.

The state is to be congratulated on the timely appearance of this report and will reap the benefits which accrue from early occupation of the field.

"The paper on the 'Silver Creek Hydraulic Limestone,' by Mr. C. E. Siebenthal, contains full details regarding the location and stratigraphy of the stone so largely used in southern Indiana for the manufacture of natural rock cement, as well as an historic, descriptive, and statistical account of the industry. It is accompanied by a map showing the exact location of the cement rock."

Of the Bedford limestone[1] there was quarried in 1900 some 7,035,000 cubic feet, with a value of $1,699,649.

---

[1] The article on this subject contributed to the current report by the writer, was made to read "Indiana Oolitic Limestone," without the consent or knowledge of the author.

From the report of the state mine inspector we learn that the production of coal in 1900 reached the largest figure in the history of the state, being 6,351,976 tons, valued at $4,883,024.18.

In a paper on the petroleum industry, the state geologist supplements his articles in the Twenty-first and Twenty-second reports, by noting recent developments in the main Indiana field, as well as in several smaller fields recently exploited. The paper is accompanied by a map of the field. The oil and gas reservoirs of the state are found to be mainly in the porous dolomitic upper portion of the Trenton limestone which does not appear at the surface anywhere in the state. The author conceives the dolomitization to have resulted from the concentration of sea water in the shallow indentations of the coast or marginal lakes, with resulting substitution of magnesium for calcium in the rock below. The total production of oil in 1900 was over 5,000,000 barrels, valued at about $5,000,000, one dollar per barrel.

The last paper in the report is from the pen of Dr. E. M. Kindle, and is entitled, the "Devonian Fossils and Stratigraphy of Indiana." It is one of the most important contributions which has ever been made to the knowledge of the paleontology of the state, and, with the exception of Dr. Foerste's work on the Silurian, is the only attempt which has been made to systematically explore the faunas of a group of Indiana rocks.

The first part of the paper takes up in detail the stratigraphy of the various localities, and discusses their faunal relations and correlation. The discovery at Delphi, Ind., of a new fauna in the New Albany shale leads Dr. Kindle to regard that formation as the western equivalent of both the Portage and Chemung, instead of the latter alone. Another interesting fact is that the Devonian limestones, which are well differentiated into the Sellersburg beds and the Jeffersonville limestone in the southern part of the state, give way to the dolomitic Geneva limestone and the Pendleton sandstone in the middle area, but resume their double facies again in the Wabash region, noting, however, that the Sellersburg beds hold very different faunas in the two regions.

The second part of the paper deals with the paleontology of the Devonian beds. The specific descriptions are preceded by keys for the discrimination of the species attributed to each genus, and these, taken in connection with the thirty-one excellent plates, comprising more than three hundred figures, make the paper an exceedingly useful handbook of this formation, particularly for Indiana students.

C. E. SIEBENTHAL.

Summary Report of the Geological Survey Department [of Canada] *for the Year 1900.* Ottawa, 1901.

Among the more interesting features of the work of the year are (1) a series of experiments in separating the magnetic element from black auriferous sands by a magnetic separator, and thereby concentrating the gold in the non-magnetic residues (collected by J. C. Gwillim, treated by J. B. Porter); (2) the discovery of salt at St. Grégoire in a red formation referred to the Medina, which throws light on the conditions attending the origin of that formation in common with other red sand and marl deposits; (3) a survey by J. McAvoy of the Crows Nest coal field, which is estimated to contain over 22,000,000,000 tons of workable coal of excellent coking qualities and low percentage of ash or other deleterious substances; (4) additional discoveries of Cretaceous coal in northern British Columbia, indicating that "the coal-bearing Cretaceous rocks occupy a much larger area than had been supposed between the 55th and 57th parallels of latitude, while anthracite coals have actually been found in the region about the head-waters of the Skeena and Stikine rivers" (J. S. O'Dwyer and A. H. Dupont); (5) a further report on the Klondike district, dealing with its indurated series and its gravels, gold and copper deposits, lignites, and glaciation (R. G. McConnell); (6) the exploration by J. C. Gwillim, of the Atlin district (about 60° lat. and 134° long.); (7) additional results in the Kootenay district; (8) an outline of explorations, by J. M. Bell, about Great Bear Lake and Great Slave Lake; (9) a brief statement of work on the crystalline area northwest of Lake Superior, by William McInnes; (10) a report of work north of Lake Superior, by Robert Bell, relating especially to iron ore developments; (11) studies, by W. A. Parks, in the Muskoka district; (12) examination of the region south and east of Ottawa, by Dr. Ells; (13) studies in the vicinity of Montreal, by O. E. LeRoy; (14) the examination of Shefford Mountain, by J. A. Dresser; (15) work in the Lake St. John district, by G. A. Young; (16) work on the great slate belt of New Brunswick, by L. W. Bailey, in which fossils indicating Ordovician and Cambrian ages were found; (17) investigations on the surface geology of northwestern New Brunswick, by R. Chalmers; (18) work in Nova Scotia on the coal field, by H. Fletcher and M. H. McLeod, and on the gold field by Mr. E. R. Faribault; (19) outlines of chemical, paleontological, and natural history investigations.

The preliminary determination of the geologic series of the Atlin district is as follows:

1. Sandstones and argillites of probable Cretaceous age, in the basins of southern Taku arm and Atlin Lake, with an expected continuation to the southeast by Pike Lake, and the Nakina River.

2. The characteristic rocks of Pine Creek basin are different varieties of magnesian combinations, together with some greenstones of a diabasic character. Magnesite, serpentine, dunite, greenstone, actinolite slates and a very friable gray limestone are the chief rocks. These were not seen outside of the Pine Creek and McKee Creek basins excepting in two or three localities. They extend in patches across Atlin Lake westward into Taku inlet and possibly over towards Taku arm to a point five miles south of Toochi River. Another area of these typical rocks is found about Chehalis Creek, south of Gladys Lake, as mentioned previously.

3. Cherty quartzites and various kinds of clay-slates, together with patches of gray or black limestone distributed over the great flats west of Dawson Peaks and Gladys Lake, O'Donnel River basin, and eastwards to Teslin Lake at its southern end.

4. Great masses of crystalline limestones on northern Taku arm, Little Atlin Lake, Lower O'Donnel River, and at the junction of Silver Salmon and Nakina Rivers.

5. Late eruptive rocks of basaltic and porphyritic characters, all about the southern parts of Atlin Lake, constituting the central portions of most of the groups of mountains there.

6. Granites of the Coast Range at the south end of Taku arm, and isolated masses of granite from the northern end of Atlin Lake eastwards across Surprise Lake, and Snowdon Mountains to near Teslin Lake; also McMaster Mountains east of Lower O'Donnel River, and the bowlder-stream plateaus seventeen miles eastward, from Ruth Lake on the Taku trail.

The conclusions relating to the ages of the rocks in the Kootenay district are as follows:

The crystalline gneisses and schists are of uncertain age, probably they include rocks of different age, but they are, at all events, among the oldest rocks of the district. The Nisconlith rocks are Lower Paleozoic, supposed to be about Cambrian. The Cache Creek rocks are Upper Paleozoic, probably Carboniferous. This is the age also assigned to most of the greenstones (andesites, porphyrites, serpentines, etc.), and the limestones and argilites associated with them. Some of the andesite and agglomeratic rocks in the Trail Creek district are no doubt younger, but there is no definite information regarding their age except that they are older than the conglomerates and the Rossland granite. The gray granite which cuts the greenstones is probably about Jurassic. The monzonite-like rocks appear to be younger than the gray granite, which would indicate that they belong to the Cretaceous.

The conglomerates are amongst the younger rocks. The Lake Mountain conglomerate is supposed by Mr. McConnell to be Tertiary. It bears a strong resemblance, both lithologically and stratigraphically, to the conglomerates associated with the Tertiary volcanics on the Kettle River, which are supposed to be of Tertiary age. The Rossland granite, which sends dykes through the conglomerates both on Sophie Mountain and on the Kettle River, is evidently younger than these. Dr. Dawson has observed granite very much like the Rossland granite, cutting the Cretaceous rocks, in the Kamloops district. The Rossland granite, again, is newer than some of the basalts, as inclusions of the latter were found in it, and reddish porphyry dykes, seemingly identical with those from this granite, were observed cutting the lower volcanic beds. There seems good ground, therefore, for supposing this granite and the accompanying porphyries to be Tertiary (R. W. Brock).

C.

Aus den Hochregionen des Kaukasus. Wanderungen Eslebnisse, Beobachtungen von GOTTFRIED MERZBACHER. Two volumes, 1920 pages, 246 illustrations from photographs, 3 maps. Leipzig: Duncker & Humblot, 1901. Price, 40 marks.

This is another great work on the Caucasus, which may be compared favorably with that by Freshfield. The two large volumes by Merzbacher deserve a more extended review than it is possible to give them at this time. They present in very attractive form the result of much labor in exploring the peaks and snowfields, the glaciers and valleys of the lofty Caucasus, as well as in study and observation of the country and its peoples. Much labor has also been bestowed upon the preparation of the book, which appears in the character of the 246 illustrations, most of which, from photographs taken by the author, have been redrawn with great success artistically, especially those by E. T. Compton. The three topographic maps of the region, on a scale of 1 : 140,000, furnish a great deal of valuable detail. A most convincing evidence of the care taken with the preparation of the book is the index of 117 double-columned pages. So also are the frequent bibliographic references.

The first chapters are devoted to the general discussion of the orography and structure of the high Caucasus; their glaciers, hydrography, passes, and subdivision into three groups, western, central, and eastern. Then follows a comparison of these mountains with the Swiss Alps, in which the Caucasus is shown to excel in loftiness and grandeur of peaks and mountain masses, and in wildness and solitude. But the Swiss Alpine valleys surpass those of the Caucasus in the charm of their beauty and restfulness. There are chapters on the ethnology of the peoples inhabiting the region, and an historical sketch of the explorations of the mountains.

These chapters are introductory to the narrative of the explorations by Merzbachen, who, as an Alpine climber, undertook the ascent of the loftiest and most forbidding peaks. The narrative begins with his departure from Munich in 1891, and the details of the journeys are presented with such thoroughness as to constitute a veritable guide-book of the country traversed. Passing through Batum and Kutais to Tschwelieri, the mountains are entered by way of the Lahpari Pass. Following an unsuccessful attempt on Ushba, are the ascents of the Laila and the Tetnuld, the crossing of the Adur-see Pass into the Baksan Valley, the ascent of Elbrus and a series of high peaks east to Kasbek, which, with a journey to Tiflis completes the experience of the first season. The second expedition, in the summer of 1892, was directed to the eastern portion of the range, and a number of lofty peaks ascended, including Tebulos-mta, Komito tawi, and Donos-mta.

The book finishes with a chapter on the map of the mountains and a discussion of the names applied to the peaks and passes; also a petrographical description of rock specimens and fossils collected by the author and studied by Dr. Ludwig von Ammon. Finally, there is a statement of all things possibly needed for such an expedition: clothing, camp outfit and provisions, apparatus, medicines, and presents suitable for those whose favors could not be repaid with money.

J. P. I.

The Geological History of the Rivers of East Yorkshire [England]; being the Sedgwick Prize Essay for the Year 1900. By F. R. Cowper Reed, Trinity College, Cambridge.

In this study the modern physiographic mode of working out the history of topographic and drainage systems is employed with apparent success, following confessedly American precedents. The general conclusions are thought to apply to East England, and perhaps more widely. They are set forth as follows:

By the preceding examination of the geological and physical evidence we have traced the general outlines of the evolution of the present drainage system of East Yorkshire through several successive stages, and we find that its history is intimately bound up with that of the whole of Eastern England since Palæozoic times. There are local details still waiting to be filled in, and branches of the subject still to be investigated, but it is believed that they will produce no evidence which will contradict the main results here worked out. The division of the physical history of the region since Cretaceous times into six stages or cycles is based on geological evidence which is practically incontrovertible; the assumptions as to the original slope of the surface and the deformation of the peneplain are supported by orographical measurements and geotectonic considerations of great weight, as well as by being in harmony with evidence from other parts of England; and, finally, the theory of consequent and subsequent streams has been established on a firm foundation by Davis and many other workers in the same field. The hypothesis of the secondary origin of the Moorland anticlinal as a watershed more or less parallel to the original consequent streams has been found to afford a natural and satisfactory explanation of the behavior and characters of the water courses which it concerns; and the modifications effected by the glacial period have been interpreted in most cases from direct field-evidence.

T. C. C.

The Conveyance of Water in Irrigation Canals, Flumes, and Pipes. By Samuel Fortier. [Bulletin No. 22, Water Supply and Irrigation Papers, Division of Hydrography, United States Geological Survey.]

The paper calls attention to present practices in the conveyance of water in the irrigated districts in different parts of the arid West and points out ways in which works of this character may be built with greater permanence and at less cost than those now in existence. As the relation of the cost of delivering water to the value of the crop to be raised is the vital question in irrigation, this paper should be of especial value to those in anyway affected by the results of irrigation.

The report gives a comprehensive review of the various kinds of irrigation canals and ditches, discussing the faults and merits of each and dwelling on such problems of their operation as the effects of too great or too little grade, the growth of aquatic plants and their removal, the accumulation of ice in winter, and the flow of water as affected by the nature and condition of the conduits.

Considerable attention is given to the construction and serviceability of various kinds of wooden flumes, and their development from the simpler and cruder forms to the expensive but more satisfactory flumes and pipes. There is also a section devoted to the discussion of the cast iron pipes, their history in irrigation, durability and cost.

Copious illustrations and diagrams accompany the report and materially add to its value. As the extent of arid land in the United States is so vast, fully two thirds of its area, and includes some of the richest agricultural land on the globe, this information regarding the methods and growth of irrigation will be welcomed.

G. B. H.

The University Geological Survey of Kansas. Volume IV, Paleontology, Part II. By SAMUEL W. WILLISTON, Paleontologist.

This part two of the paleontology of Kansas is devoted to the description of the Carboniferous invertebrates and the Cretaceous fishes.

The Carboniferous invertebrates, from the Protozoa to Pelecypoda inclusive, have been discussed for the report by Dr. J. W. Beede. All the species have been fully described, so that the report will be a valuable manual for the study of Upper Carboniferous or Coal-measure invertebrates. Not since Meek's report on the Coal-measure faunas of eastern Nebraska, published in 1872 in the final report of the U. S. Geological Survey of Nebraska, has there appeared so comprehensive a report of the faunas of this age, and the report will be of great value to all workers in Upper Carboniferous paleontology whether in Kansas or elsewhere. The paper is illustrated by twenty-two plates. The completion of the report, including the treatment of the additional classes of invertebrates, is promised for the next part of the Paleontology of Kansas to be published by the Survey.

The literature on the Cretaceous fishes of Kansas has been widely scattered in the past, much of it having been published in Germany from collections secured from Kansas for the museums of German univerities, and has been for the most part inaccessible to American students who have not had access to large libraries. In the present report the Selachians and Pycnodonts have been treated by Dr. S. W. Williston, and the Teleosts by Mr. Alban Stewart. These two papers together constitute a comprehensive report of the Kansas Cretaceous fishes and are a valuable contribution which will be of use not only to the citizens of Kansas, but to all students of fossil fish.

S. W.

Profiles of Rivers in the United States. By HENRY GANNETT. Water-Supply and Irrigation Paper No. 44, United States Geological Survey.

This interesting and valuable publication embodies within a hundred pages the leading facts of about one hundred and fifty of the most important rivers and streams of the country, noting their length, drainage area, the location of water power in their courses, their peculiarities of flow, and the nature of their drainage basins.

The rivers selected are those which are the largest in size and bear most directly upon the varied interests of the country, such as the Connecticut, Hudson, Susquehanna, Ohio, Potomac, Mississippi, Missouri, Platte, Colorado, Sacramento, Columbia, and others. The figures for the tables showing height above sea level and fall per mile were collected from various sources; some were obtained from the report of the chief engineer of the United States army, some from railroad companies when their lines cross streams, and some from the Atlas sheets of the United States Geological Survey.

In the case of such rivers as the Connecticut, Susquehanna, Mississippi, and Colorado, where the surrounding country is, in part or whole, of peculiar physiographic interest, very excellent and vivid descriptions of its leading physical characteristics are given. The pamphlet is the result of much careful work, and is the first attempt to collect and compile this information in its present form.

G. B. H.

Yearbook of the United States Department of Agriculture for 1900. Washington, 1901.

The portions of this important volume of most interest to geologists are those which relate to soil investigation and the special papers on "Mountain Roads," by James W. Abbott: "The Selection of Materials for Macadam Roads," by Logan Waller Page; "Objects and Methods of Investigating Certain Physical Properties of Soils," by Lyman J. Briggs; and "Practical Irrigation," by C. T. Johnston and J. D. Stannard.

C.

RECENT PUBLICATIONS

—American Museum of Natural History. Annual Report for the year 1900. New York, 1901.

—Australasian Institute of Mining Engineers, Transactions of. Vol. VII. Melbourne, 1901.

—BALDWIN, EVELYN B. Meteorological Observations of the Second Wellman Expedition. [Report of the Chief of the Weather Bureau, U. S. Department of Agriculture, 1899–1900, Part VII.] Washington, 1901.

—BARBOUR, ERWIN HINCKLEY. Sand Crystals and their Relation to Certain Concretionary Forms. Bull. of the Geol. Soc. of Am., Vol. XII, pp. 165–172, plates 13–18. Rochester, April 1901.

—BLAKE, JOHN CHARLES. A Mica-Andesite of West Sugarloaf Mountain, Boulder County, Colorado. Some Relations of Tetrahedral Combinations to Crystalline Form. [Proceedings of the Colorado Scientific Society, Vol. VII, pp. 13–36.] Denver, April 1901.

—BLAKE, WILLIAM P. Some Salient Features in the Geology of Arizona with Evidences of Shallow Seas in Paleozoic Times. [Reprinted from the American Geologist, March 1901.]

The Caliche of Southern Arizona: An Example of Deposition by the Vadose Circulation. [Transactions of the American Institute of Mining Engineers. Richmond meeting, February 1901.]

—Canada, Summary Report of the Geological Survey Department for the year 1900. Ottawa, 1901.

—COLEMAN, A. P. Marine and Freshwater Beaches of Ontario. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 129–146.] Rochester, March 1901.

—Congrès Géologique International (8th Session) Tenu à paris du 16 Aout, 1900. Proces-Verbaux des Séances. Ministère du Commerce de L'industrie, des Postes et des Télegraphes. Exposition Universelle Internationale de 1900. Direction Générale de L'Exploitation. Paris, 1901.

—CRAGIN, F. W. A Study of some Teleosts from the Russell Substage of the Platte Cretaceous Series. [Reprinted from Colorado College Studies, Vol. IX.] Colorado Springs, Colorado, May 1901.

—DAVIS, W. M. An Excursion to the Grand Canyon of the Colorado. [Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXVIII. Geological Series, Vol. V, No. 4.] With two plates. Cambridge, Mass., May 1901.

—Edinburgh Geological Society, Transactions of the. Vol. VIII, Part I. Edinburgh and London, 1901.

—Ells, R. W. Ancient Channels of the Ottawa River. [Reprinted from the Ottawa Naturalist, Vol. XV, No. 1, pp. 17–30, April 1901, Ottawa, Canada.]

The Physical Features and Geology of the Paleozoic Basin between the Lower Ottawa and St. Lawrence Rivers. [From the Transactions of the Royal Society of Canada, Second Series, 1900–1. Vol. VI. Section IV, Geological and Biological Sciences.] Ottawa and Toronto, Canada, and London, England.

—Gannett, Henry. Profiles of Rivers in the United States. [Water Supply and Irrigation Papers of the United States Geological Survey, No. 44.] Washington, 1901.

—Grabeau, Amadeus W. Lake Bouvé. An Extinct Glacial Lake in the Boston Basin. [From the Occasional Papers of the Boston Society of Natural History, Vol. IV, Part III.] Author's edition, issued July 1900. Boston.

—Hale, George E. Changes in the Spectrum of Nova Persei. The Yerkes Observatory of the University of Chicago, Bulletin No. 17. The University of Chicago Press, 1901.

—Hay, O. P. The Chronological Distribution of the Elasmobranchs. [Reprinted from Transactions of Amer. Philos. Soc., Vol. XX.]

—Indiana: Department of Geology and Natural Resources. Twenty-fifth Annual Report, 1900. W. S. Blatchley, State Geologist. Indianapolis, Ind., 1901.

—Keyes, Charles R. A Depositional Measure of Unconformity. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 173–196, plate 19]. Rochester, 1901.

—Kümmel, Henry B., and Stuart Weller. Paleozoic Limestones of Kittatinny Valley, New Jersey. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 147–164.] Rochester, April 1901.

—Lambe, Lawrence M. Contributions to Canadian Palæontology, Vol. IV (Geological Survey of Canada). Part II. A Revision of the Genera and Species of Canadian Paleozoic Corals; the Madreporaria Aporosa and the Madreporaria Rugosa. Ottawa, 1901.

Notes on a Turtle from the Cretaceous Rocks of Alberta. [Reprinted from the Ottawa Naturalist, Vol. XV, No. 3, pp. 63–67, June 1901, Ottawa, Canada.]

—Marsh, C. Dwight. The Plankton of Fresh Water Lakes. [Reprinted from the Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, Vol. XIII.]

—Maryland and Its Natural Resources. Prepared by the Maryland Geological Survey, William Bullock Clark, State Geologist. [Official Publication of the Maryland Commissioners Pan-American Exposition.] Baltimore, 1901.

—Maryland Geological Survey. Eocene. The Johns Hopkins Press, Baltimore, 1901.

—MATTHES, FRANCOIS E. Glacial Structure of the Bighorn Mountains, Wyoming. [Extract from the Twenty-first Annual Report of the United States Geological Survey, 1899–1900: Part II—General Geology, Economic Geology, Alaska.] Washington, 1900.

—MERRIAM, JOHN C. A Contribution to the Geology of the John Day Basin. [Bulletin of the Department of Geology, University of California, Vol. II, No. 9, pp. 269–314.] Berkeley, April 1901.

—MERZBACHER, GOTTFRIED. Aus den Hochregionen des Kaukasus (2 volumes). Verlag von Duncker & Humblot, Leipzig, 1901.

—New York Academy of Sciences, Annals of the. Vol. XIII, Parts II and III. Editor, Charles Lane Poor; acting editor, Theodore G. White. Published by the Academy.

—Ohio, The Preglacial Drainage of. Comprising the Results of Researches made by Members of the Academy of Science, by the Aid of the McMillin Research Fund. (Ohio State Academy of Science, Special Papers No. 3.) Papers by W. G. Tight, J. A. Bownocker, J. H. Todd, M.D., and Gerard Fowke.

—OLDHAM, R. D. Origin of the Dunmail Raise (Lake District). [Reprinted from the Quarterly Journal of the Geological Society, Vol. LVII, May 1901, pp. 189–197.]

The Great Earthquake of June 12, 1897. [Estratto dal Boll. della Soc. Sism. Ital. Vol. VI.] Modena, 1900.

—Philosophical Society of Washington, Bulletin of the. Vol. XIII, 1895–1899. Washington, 1900.

—PRATHER, JOHN K. On the Fossils of the Texas Cretaceous, especially those Collected at Austin and Waco. [Reprinted from the Transactions of the Texas Academy of Science, Vol. IV, Part I, 1900.]

—PROSSER, CHARLES S. The Classification of the Waverly Series of Central Ohio. [Reprinted from the JOURNAL OF GEOLOGY, Vol. IX, No. 3, April–May 1901.] The University of Chicago Press.

—RABOT, CLARLES. Le conflit chilo-argentin et les phénoménes de capture dans la Cordillère des Andes. [La Géographie Bulletin de la Société de Géographie. Extrait du No. 4, April 1901.]

—Rathbun, Richard. Report upon the Condition and Progress of the U. S. National Museum during the Year ending June 30, 1899. [From the report of the U. S. National Museum for 1899, pp. 1–152.] Washington, 1901.

—Reed, F. R. Cowper. The Geological History of the Rivers of East Yorkshire. (Being the Sedgwick Prize Essay for the year 1900.) C. J. Clay & Sons, Cambridge University Press Warehouse, 1901.

—Ries, Heinrich. Clays and Clay Products at the Paris Exposition of 1900. [Extract from the Twenty-first Annual Report of the U. S. Geological Survey, 1899–1900; Part VI (continued) Mineral Resources of the United States, Calendar Year 1899: David T. Day, Chief of Division of Mining and Mineral Resources.] Washington: 1901.

—Shattuck, George Burbank. The Pleistocene Problem of the North Atlantic Coastal Plain. [From the Johns Hopkins University Circulars, No. 152, May 1901.]

—Smithsonian Institution, Annual Report of the Board of Regents, showing the Operations, Expenditures, and Condition of the Institution for the Year ending June 30, 1899. Washington, 1901.

—South Australia, Record of the Mines of. Report on Geological Exploration of the Tarcoola District, with Plan. H. Y. L. Brown, Government Geologist. Adelaide, 1901.

—The State of Progress of our Knowledge of the Tides. By L. P. Shidy. Bulletin of the Philosophical Society of Washington, Vol. XIV, pp. 117–127. [Being a portion of the Report of the Committee on Physical Science for 1900.] Washington, March 1901.

—The Tendency of Methods for the Measurement of the Force of Gravity on the Ocean. By G. W. Littlehales. Bulletin of the Philosophical Society of Washington, Vol. XIV, pp. 135–137. [A part of the Report of the Committee on Physical Science for 1900.] Washington, March 1901.

—United States Department of Agriculture: Division of Soils. List of Soil Types established by the Division of Soils in 1899 and 1900, with brief description.

—United States Department of Agriculture, Yearbook of the, 1900. Washington, 1901.

—Van Den Broeck, Ernest. Le Dossier Hydrologique du Régime Aquifere en Terrains Calcaires et le Rôle de la Géologie Dans Les Recherches et Études des Travaux d'Eaux Alimentaires. Brussels, April 1901.

—Vogt, J. H. L. Sõndre Helgeland. No. 29, Norges Geologiske Undersõgelse. Kristiania, 1900.

—WALCOTT, CHARLES D. Report upon the Condition and Progress of the U. S. National Museum during the Year ending June 30, 1898. [From the Report of the U. S. National Museum for 1898, pp. 1–149.] Washington, 1900.

—Ward-Cooney Collection of Meteorites, The. Henry A. Ward, 620 Division street, Chicago, 1901.

—Washington Academy of Sciences, Proceedings of the: Papers from the Harriman Alaska Expedition, XXI, The Hydroids. By C. C. Nutting. Vol. III, pp. 157–216, May 11, 1901. Pls. XIV–XXVI. Washington, 1901.

—WHITE, DAVID. Some Palæobotanical Aspects of the Upper Palæozoic in Nova Scotia. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 5, for January 1901, issued January 15, 1901.]

—WHITFORD, H. N. The Genetic Development of the Forests of Northern Michigan; a Study in Physiographic Ecology. Contributions from the Hull Botanical Laboratory, XXVII. [Reprinted from the Botanical Gazette, Vol, XXXI, May 1901.] The University of Chicago Press.

—WICHMANN, ARTHUR. Der Ausbruch des Gunung Ringgit auf Java im Jahre 1593. [Abdruck aus der Zeitschrift der Deutschen geologischen Gesellschaft Bd. LII, Heft 4, 1900.]

—WILLISTON, SAMUEL W. The University Geological Survey of Kansas. Vol. VI. Paleontology. Part 2, Carboniferous and Cretaceous. Topeka, 1900.

—WOOSTER, L. C. The Geological Story of Kansas. Twentieth Century Classics and School Readings, Vol. II, No. 1, March 1900. [Edited by W. M. Davidson, Superintendent of the Public Schools of Topeka, Kan.] Crane & Co., Topeka.

THE

JOURNAL OF GEOLOGY

JULY–AUGUST, 1901

ON A POSSIBLE FUNCTION OF DISRUPTIVE APPROACH IN THE FORMATION OF METEORITES, COMETS, AND NEBULÆ.[1] [2]

According to a familiar doctrine founded on the researches of Roche, Maxwell, and others, a small body passing within a certain distance (the Roche limit) of a larger dense body will be torn into fragments by differential attraction. In reality, the doctrine is applicable to the close approach of any two bodies of sufficient mass and density, but, as this more familiar case of a small body in close approach to a larger body is the one supposed to be involved in the origin of comets and certain meteorites, it will at first be taken as representative, and the wider application of the doctrine will be considered later.

The sphere defined by Roche's limit is computed on the basis of a liquid body whose cohesion is negligible, and whose self-gravitation alone is considered. It is obvious, therefore, that when cohesion is a notable factor, a small body might pass through the outermost part of this Roche sphere without suffering disruption, but that, if a nearer approach were made to the large body, fragmentation might take place. There is, therefore, a sphere within the Roche limit—which may be called the sphere of disruption—which is applicable to solid bodies as distinguished from liquid bodies.

---

[1] I am greatly indebted to Dr. F. R. Moulton for suggestions and criticisms, and for formulæ for certain auxiliary computations that do not appear in the paper. I am under obligations to Mr. C. E. Siebenthal for the diagrams and other aid.

[2] From The Astrophysical Journal, Vol. XIV, No. 1, July 1901.

The size of this sphere of disruption compared with the Roche sphere depends, among other things, on the coefficient of cohesion and the size of the body to be disrupted. The coefficient of cohesion being the same, the sphere of disruption is relatively smallest when small bodies are to be disrupted, and becomes larger as the size of the body increases until it is sensibly as large as the Roche sphere. To illustrate this concretely, let disruption be supposed to take place along a diametrical section normal to the gravitative pull, dividing the body into halves. Let the bodies to be disrupted be spherical and homogeneous. The cohesion to be overcome will then obviously vary as the areas of the diametrical sections, and these areas vary as the squares of the radii of the bodies. But the masses of homogeneous spheres vary as the cubes of their radii, and the gravitative pull varies as the masses, modified by the differential tidal pull. It follows that mutual gravitation will more effectively disrupt large bodies than small ones. The limit at which the fragmentation of a solid body will take place will therefore approach more and more closely that of a fluid body as the size of the solid body becomes larger. For solid bodies of considerable dimensions, as asteroids, for example, the limit of disruption approaches sufficiently near Roche's limit to make the difference negligible in a general discussion. This will appear the more evident from the following numerical considerations.

Experimental data as to the tensile strength of rock are very limited, as the material is rarely used where tensile stresses are involved, but all the results of experimental tests given in Johnson's *Material of Construction* fall notably below 1000 pounds to the square inch, and this figure may be assumed as a liberal representative estimate. The weight of representative rock may be taken as $\frac{1}{10}$ pound per cubic inch. The tensile strength of an inch cube is therefore to its weight, at the surface of the earth, as 10,000 to 1. Using the same data, the tensile strength of a mile-cube of rock is to its weight as 1 to 6.36, while that of a 100-mile-cube is as 1 to 636. It will be seen, therefore, that in a comparatively small body the cohesive resistance to disruption bears a very small relation to the gravity of the mass, and that for large bodies it is negligible. For such bodies, the Roche limit may be taken as appreciably the limit of the sphere of disruption.

These numerical considerations, however, show that fragmentation by differential gravity acting alone will not become minute in any such case as that of a satellite or asteroid making a near approach to one of the planets.

But there are additional considerations that influence the practical result. The outer portion of the earth, and doubtless that of the satellites, asteroids, and cold planets generally, is deeply traversed by fissures—oblique and horizontal as well as vertical—which render it little more than a pavement of dissevered blocks which could be lifted away with little resistance beyond that of gravity. The relief of pressure upon the less fissured portion below, which would follow upon the removal of the overlying fissured portion, and the sudden exposure of this under portion to a lower temperature resultant from this removal, would develop new stresses; and these would doubtless give rise to additional fissuring and further easy removal, and thus the process would be extended. It is not improbable that the sudden rending open of a sphere that is hot within and the consequent exposure of the highly heated rocks in the interior to much lower temperatures would result in sufficiently great differential contraction to minutely disrupt the fragments irrespective of differential gravitation. The central portions of a body sufficiently hot to melt at surface pressures would doubtless pass immediately into the liquid condition on the removal of the pressure of the overlying rock, and this passage might, not unlikely, take on eruptive violence by reason of the included and highly compressed gases—or substances in a potentially gaseous state—in which case an extremely minute division would ensue. In the case of the earth, there is good reason to believe that if its interior gravitative stresses were suddenly removed, its internal elasticity would disrupt its exterior with much violence; and if the gravitative stresses were more gradually removed, the disruption would still be complete and pervasive, though less violent. How far a similar view may be entertained with reference to small bodies like the asteroids is uncertain, but even in these it is not improbable that the internal elastic factors would offset in some large part, if not entirely, the restraining force of the general cohesion of the mass.

From these considerations it would seem that the sphere of disruption, even in solid bodies of the nature of satellites and asteroids, may closely approximate to the theoretical Roche limit, while, for large bodies intensely compressed and very hot within, the practical sphere of disruption might actually exceed the Roche sphere. In the case of large gaseous bodies like the sun, intensely heated and compressed in the central portions, the disruptive or dispersive sphere must be much larger than the Roche sphere. But of this later. For the smaller solid bodies, and for present purposes, it may be assumed that the sphere of disruption is practically defined by Roche's limit.

The size of the sphere of disruption compared with the size of the body producing the disruption is an essential point in this discussion. The relative magnitude of these varies for every couplet of bodies brought under consideration, because it is dependent on density, cohesion, internal elasticity, and other varying factors. Roche has shown that, if the two bodies are incompressible fluids of the same density, and without cohesion, the limit of disruption is 2.44 times the radius of the body producing the disruption. The cross section of this body will therefore be to the cross section of the Roche sphere as 1 is to 5.95. The disk of the outer ring of *Saturn*, compared with that of the planet, whose density is unusually low, is a trifle below this ratio (1:5.29), but may be taken as a practical sanction of the figure theoretically deduced. The disk of the Earth, a dense body, is to the disk of the Roche limit, as computed by Darwin, as 1 to 7.5. It may therefore be concluded that where planets and planet-like bodies are concerned, the sphere of disruption has a cross section from 5 to 7.5 times as great as the central body It follows from this, that to a passing body the sphere of disruption exposes a disk five to seven times as great as the central body, and hence there are from four to six times as many chances that the passing body will invade the sphere of disruption without collision, as that it will strike the central body. In other words, *the fragmentation of a small body by near approach to a large one of the nature of the planets will be from four to six times as imminent as actual collision.*

That disruptions or explosions of some kind actually take place in the heavens, and that not uncommonly, seems to be implied by the sudden appearance of new stars, often with great brilliancy, followed by rapid decline to obscurity or extinction.[1] Five such new stars have been recorded during the last decade, and the survey of the heavens during this period has not been entirely exhaustive. The appearance of such new stars has been referred to collision, but their frequency has been felt to be an objection to this view, and other explanations, of the nature of eruptions or explosions, have been offered, but usually without assigning any probable cause for such extraordinary explosive action. The numerical objection is, in some measure, removed if the possibilities of disruptive approach be added to those of collision; and it will be seen further on that special conditions giving rise to distant approaches that are merely disturbing at the outset, may ultimately give rise to large possibilities for disruptive approaches.

That bodies pass within the disruptive sphere of other bodies is known from the fact that at least four comets have been observed to pass within the Roche limit of the sun, and these would quite certainly have been torn into fragments if they had not already been in that condition. There are, therefore, some observational grounds for the view that instances of bodies passing through the disruptive spheres of other bodies are not so rare as to render their results unimportant.

---

[1] A fact which has become very familiar and impressive, since this was written, by the appearance of *Nova Persei.*

In the considerations now set forth, there seems to be warrant for the proposition *that solid bodies may suffer fragmentation without actual collision with other bodies, and that the bodies so disrupted may constitute comets so long as the fragments remain clustered, and that when these fragments become dispersed, they may constitute one variety of meteorites.* Only the first part of the proposition is novel—if indeed that is—for the disintegration of comets into meteorites is an accepted doctrine. The characteristics of comets other than their fragmental structure will need to be considered, but this may best be taken up later.

The foregoing conclusion, as a purely ideal proposition, does not appear to need discussion, unless the fundamental deductions of Roche, Maxwell, and others are questioned. Nor does its application to the adventitious cases of wandering bodies permit definite discussion, for neither the nature nor the number of such bodies is known; nor is the likelihood of their close approach to other bodies capable of estimation. But, on the probable supposition that the stars are centers of systems like our sun, there are hypothetical cases of approach of these systems to each other that by disturbance of the planetary orbits may lead on to disruptive approach of the individual bodies, and thus give effective application to the doctrine; and these invite consideration. It must be confessed that these cases, likewise, cannot be discussed with much satisfaction, since the movements of the assumed solar systems and their relations to each other are but very imperfectly known. Present data, however, warrant the assumption that the stars and their attendants are moving in various directions at various velocities, and that they are probably not controlled by any central body; nor do they probably follow concentric orbits so adjusted to each other as to forbid close approaches. The conception that the movements of the stars are somewhat analogous to those of the molecules of an exceedingly attenuated gas in an open space, actuated by the attraction of their common but dispersed mass, seems the most probable that can be entertained in the present state of knowledge. It may at least be made the basis for the assumptions necessary to further discuss the doctrine in hand.

Let two stars be assumed to be attended by secondaries like those of the sun, and to pass each other near enough to initiate serious disturbances in the orbits of the planets and satellites of the two systems. It is not necessary that this disturbance shall be so great as to bring about a disruptive approach of any of these bodies at once, but merely that this shall be the ulterior effect, which may be long delayed. The two systems need not necessarily invade each other's actual limit, that is, the two suns need not approach each other within the sum of the radii of the orbits of their outermost planets.[1] For example, in the ideal case of two solar systems, it is not necessary that the orbits of the two *Neptunes* shall actually cut each other. If the undisturbed orbits merely touch each other, or even closely approach each other, it seems clear that if *Neptune* be at the time coming toward the point of such ideal contact, or near approach, the attraction of the passing sun, together with *Neptune's* own momentum, will carry the planet far beyond the limit of its own ideal orbit into the sphere of dominant influence of the passing sun. At the same time, the paths of the inner orbits of both systems will be distorted in a quite irregular way, dependent on their various positions in their several orbits. The transfer of an outermost planet from one system to another under these conditions of general disturbance, or any other radical change in the orbits of the outer planets, will quite certainly lead on to other disturbances of orbit, some of which may sooner or later lead to disruptive approach, though the result of such a complication is beyond the reach of precise prediction.

A still more remote approach between two systems in which the only result is a pronounced elongation of the orbits of the two systems, may ultimately result in close approaches, for, if the orbit of any of the planets of the two systems be elongated so that its perihelion distance is less than the aphelion distance of the next inner planet, or its aphelion distance greater than the perihelion distance of the next outer planet, a disruptive approach, although it will not necessarily follow, because the planes may not coincide, and for other reasons, may result—if not at once, at least ultimately—as a consequence of the shiftings and modifications which such a disturbed condition involves. For example, it is obvious that by a favorable conjunction with a passing system whose sun is distant from *Neptune* considerably more than the radius of his orbit, there may be an elongation of the orbit of *Neptune* so as to make it cut one or more of the inner orbits, and that further modifications may arise out of these relations which will either increase or decrease the eccentricity. The principles applicable here are identical with those that have been found to produce radical modifications of the orbits of comets and that have been worked out by H. A. Newton and others.

---

[1] In the illustrative examples it is assumed for convenience that the planes of the systems are normal to the systems' lines of movement.

To embrace the full possibilities of the case, it is therefore necessary to consider (1) the effects of systems passing each other at distances varying from those in which the outermost planets do not even cut each other's orbits, down to center-on-center collisions, and (2) to take account of the ulterior effects of disturbed orbits, as well as the immediate effects. This last is a consideration of no small importance in the qualitative as well as the quantitative application of the doctrine, for it distributes the effects over an indefinite period of time, and does not require their coincidence with the passage of the systems. The ulterior effects, so far as the disruption of secondaries is concerned, may apparently be much greater than the immediate effects. If this is not already clear, let a specific case be taken, as, for example, two solar systems passing each other so that their centers shall be 500,000,000 miles apart at nearest approach. If the planes of the systems are transverse to their paths, the ideal undisturbed orbits of the asteroids will touch, or closely approach, or slightly cut each other, as the individual case may be. The ideal orbits of the *Jupiters* will fall but little short of the passing sun, while the ideal orbits of *Saturn*, *Uranus*, and *Neptune* will fall outside the passing sun. While the precise results of such an event cannot be computed, it is quite certain that the secondary systems of the two suns will be most profoundly disturbed and the symmetrical and harmonious relations of the planetary orbits be utterly broken up. While even in this case the *immediate* contingency of a disruptive approach of one secondary to another may not be high, there will arise a *perpetuated series of contingencies*, the consequences of which will apparently be immeasurably greater than those immediately incident to the disturbing action, and the end of this perpetuated series of contingencies can scarcely be foreseen. Assuming that the great planets will exercise the same kind of influence over the small planets and asteroids that pass near them that *Jupiter* does over comets, the range of possible contingencies involves, on the one hand, closer and closer approaches and even collisions with the Sun and with other planets, and, on the other hand, the development of extremely elliptical orbits that will carry the small bodies into the sphere of influence of some other system. How large a proportion of these theoretical possibilities will be realized in a given disturbed system, it is impossible to determine, for the problem is far beyond the power of mathematical analysis, but it seems at least probable that results of moment may ensue.

If we may judge from the solar system, the small bodies may be assumed to be at least fifty times as numerous as the large ones, while not improbably they are a hundred or several hundred times as numerous. Other things being equal, they should show the characteristic effects of the action under discussion with correspondingly greater frequency. But the other conditions intensify these effects. A small body may be disrupted by a large one, but not necessarily the reverse. So, too, a small body may be thrown into an erratic orbit, while the orbit of the large body may not be sensibly affected, as shown by the changes in the orbits of comets caused by *Jupiter*. By far the most common effect of the close approach of two star systems should therefore be the fragmentation of the small bodies by being caused to pass within the spheres of disruption of the large bodies. As previously indicated, *the contingency of acquiring at the same time* *highly erratic orbits is imminent, and these are specially subject to still further changes, and thus these fragmental clusters come to possess by the very circumstances of their birth the second characteristic of comets, as well as the first.*

Whether they would possess at the same time, or come at length to possess, the *third* characteristic of comets, the attenuated matter of which cometic tails are made, is not so clear, since the nature of this matter and its condition are not yet fully known. The recent discoveries relative to the extreme ionization of matter and perhaps even its corpuscular dissociation, and the radio-activity of certain kinds of matter are at least very suggestive in this connection. Six of the elements reported by good authority as detected in meteorites, are known to possess, or to be habitually associated with, radio-active matter, viz., barium, bismuth, cerium, lead, titanium, and uranium. It is not very material here whether this radio-activity is really possessed by all these elements themselves, or simply by substances associated with them. If the coma and tails of comets are dependent on rare substances of a radio-active or extremely volatile nature, and hence permanently retensible only in the interior of bodies, it would be difficult to imagine conditions more favorable for setting them free in unusual volume than minute tidal disruption; particularly is this true if the retention of these substances is dependent on low temperature, as seems to be the case, since they are brought forth and driven away at a highly accelerated rate as the sun is approached. This view seems also to be supported by the fact that comets which remain long in the vicinity of the sun, as for example the short-period comets, lose their tails in a brief period.

If the attenuated cometic matter owes its essential peculiarities to electric states, these might perhaps be derivable from the revolutionary movements of the magnetic elements in the fragmental swarm, for by the hypothesis of tidal disruption the swarm should inherit a rotatory movement, and the fragments should contain both magnetic and magnetizable matter, variously associated with diamagnetic matter.

That short-period comets are subject to progressive disintegration, and that their scattered elements constitute one class of meteorites, is familiar doctrine. There seems no reason for withholding the conception from comets which have parabolic or hyperbolic orbits, for in certain cases such comets have shown signs of disruption and partial dispersion in their perihelion passages. To the dispersed elements of these comets of high velocity is assigned (in part at least) such meteorites as come to earth from diverse directions with velocities incompatible with an origin within the solar system.

It remains to consider whether the fragments derived from the disruption of an asteroid, satellite, or small planet through differential gravitative strain without collision, will satisfy the characteristics which meteorites display. Ample data for a judgment on this vital point will be found in the articles on the structure of meteorites in the first two numbers of the *Journal of Geology* for the current year, by Dr. Farrington, who, at my request, has kindly brought together in succinct and systematic form the essential characteristics of meteoric structure. A study of these characteristics will show that, while they embrace a great and very significant variety, they are all referable to the structures that are appropriate to small planets, while it is difficult to see how all of these characteristics can be found in derivatives from any of the alternative sources to which meteorites have been assigned, namely, volcanic action of the moon or of the planets, explosive projection from the sun, or individual aggregation in space. Some of the matter is fragmentary, implying surface conditions, while some of it is coarsely crystalline, implying deep-seated conditions. Some is volatile and combustible, implying the absence of high temperature throughout its whole antecedent history, while some as distinctly implies the presence of high temperature. In some meteorites the iron is segregated, while in others it is disseminated. Frequent brecciated structures imply fracturing and recementation. *Faulting and slickensides* demonstrate movements attributable to the parent body, but not to the meteorite itself. Veins imply internal

—Walcott, Charles D. Report upon the Condition and Progress of the U. S. National Museum during the Year ending June 30, 1898. [From the Report of the U. S. National Museum for 1898, pp. 1–149.] Washington, 1900.

—Ward-Cooney Collection of Meteorites, The. Henry A. Ward, 620 Division street, Chicago, 1901.

—Washington Academy of Sciences, Proceedings of the: Papers from the Harriman Alaska Expedition, XXI, The Hydroids. By C. C. Nutting. Vol. III, pp. 157–216, May 11, 1901. Pls. XIV–XXVI. Washington, 1901.

—White, David. Some Palæobotanical Aspects of the Upper Palæozoic in Nova Scotia. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 5, for January 1901, issued January 15, 1901.]

—Whitford, H. N. The Genetic Development of the Forests of Northern Michigan; a Study in Physiographic Ecology. Contributions from the Hull Botanical Laboratory, XXVII. [Reprinted from the Botanical Gazette, Vol, XXXI, May 1901.] The University of Chicago Press.

—Wichmann, Arthur. Der Ausbruch des Gunung Ringgit auf Java im Jahre 1593. [Abdruck aus der Zeitschrift der Deutschen geologischen Gesellschaft Bd. LII, Heft 4, 1900.]

—Williston, Samuel W. The University Geological Survey of Kansas. Vol. VI. Paleontology. Part 2, Carboniferous and Cretaceous. Topeka, 1900.

—Wooster, L. C. The Geological Story of Kansas. Twentieth Century Classics and School Readings, Vol. II, No. 1, March 1900. [Edited by W. M. Davidson, Superintendent of the Public Schools of Topeka, Kan.] Crane & Co., Topeka.

THE
JOURNAL OF GEOLOGY

JULY–AUGUST, 1901

ON A POSSIBLE FUNCTION OF DISRUPTIVE APPROACH IN THE FORMATION OF METEORITES, COMETS, AND NEBULÆ.[1] [2]

ACCORDING to a familiar doctrine founded on the researches of Roche, Maxwell, and others, a small body passing within a certain distance (the Roche limit) of a larger dense body will be torn into fragments by differential attraction. In reality, the doctrine is applicable to the close approach of any two bodies of sufficient mass and density, but, as this more familiar case of a small body in close approach to a larger body is the one supposed to be involved in the origin of comets and certain meteorites, it will at first be taken as representative, and the wider application of the doctrine will be considered later.

The sphere defined by Roche's limit is computed on the basis of a liquid body whose cohesion is negligible, and whose self-gravitation alone is considered. It is obvious, therefore, that when cohesion is a notable factor, a small body might pass through the outermost part of this Roche sphere without suffering disruption, but that, if a nearer approach were made to the large body, fragmentation might take place. There is, therefore, a sphere within the Roche limit—which may be called the elasticity of large hot bodies under great self-gravitative compression may so far aid in disruption, by coöperation with the differential gravity of an adjacent body, as to cause dispersion even before the Roche limit is reached. In the case of very large bodies that are already gaseous, such as the sun, this phenomenon gives rise to a special case of extreme interest. Under this special case, there arise a large variety of particular instances due to the varying sizes, velocities, paths, rotations, and constitutions of the couplets of stars concerned, and also to the adventitious effects of their secondaries; but, for a simple illustrative case, let it be assumed that two bodies of equal masses and equal velocities are approaching each other on parabolic paths, and that at periastron they will pass through each other's spheres of disruption, or rather, spheres of dispersion. For convenience, let if be assumed that one of these bodies (*A*, Fig. 1) is gaseous, while the other (*B*) has already become so cold and solid as to act essentially as a unit, though disrupted. The history of the dispersion of the gaseous body may then be followed alone. Let the rate of rotation of the gaseous body (*A*) be relatively low, as in the case of our sun. It may then be neglected in a general discussion, since as a dynamic factor it is trivial compared with the enormous energies of momentum and of elastic dispersion involved. This will appear clear in the outcome. Furthermore, the direction of rotation with reference to the parabolic paths might happen to be any one of an indefinite number, in many of which the effect would be inconsequential, even if the energy were large. In the close approach of these two bodies the two great dynamic factors of special interest are (1) the tidal distortion, and (2) the elastic expansion of the gaseous body.

---

[1] I am greatly indebted to Dr. F. R. Moulton for suggestions and criticisms, and for formulæ for certain auxiliary computations that do not appear in the paper. I am under obligations to Mr. C. E. Siebenthal for the diagrams and other aid.

[2] From THE ASTROPHYSICAL JOURNAL, Vol. XIV, No. 1, July 1901.

While the two bodies are yet distant from each other, they must begin to take on elongation of the tidal type as the result of their mutual differential attraction, this elongation being aided by the high internal mobility and elasticity of the gaseous body. As the bodies approach periastron, this elongation must progress at an accelerated rate. At the moment of the entrance of the gaseous body *A* upon the Roche sphere of the body *B*, self-gravitation, in accordance with Roche's doctrine, will have been completely neutralized on the lines joining the centers of *A* and *B*, and its restraining influence upon the elasticity of the gaseous body on these lines will have been removed, while the gravitative constraint in the transverse section will be increased. The expansive energy of the compressed gaseous matter will therefore be left to exert its full projectile force in the direction of the axis of elongation. While I am unable to offer a numerical estimate of the magnitude of this expansional energy in such a body as the sun, it is certainly of a high order of magnitude. The speed at which prominences are projected from the sun under present conditions closely approximates to the parabolic velocity with respect to the sun, and this is accomplished in spite of gravitation and a resisting atmosphere.

The case in hand, therefore, starts with simple tidal elongation at a distance, and increases to an explosive maximum as the bodies approach periastron. This increase is at first gradual, but in the last stages of approach to periastron the acceleration is exceedingly rapid. In any attempt to follow the process in more detail, adhering to the recognized principles of tidal action, four particulars are of special moment: (1) the progressive elongation of the body, (2) the change in the direction of tidal distortion, (3) the lag of the line of maximum elongation behind the line of maximum attraction, and (4) the rotatory effects arising from the gravitation of *B* on the tidal protuberances of *A*, which in this case will be peculiarly effective because of the enormous distortion of *A* and the very close proximity of *B* at the critical stages. The principles from which these effects arise are thoroughly demonstrated and are familiar to all students of tidal phenomena, and it is only their special applications to this case that need be discussed. The rotatory effects are a little peculiar in that both of the tidally acting bodies are rapidly approaching each other, and developing extraordinarily powerful differential attractions, while at the same time they are swinging about their common center of gravity. Near periastron they may be regarded as performing a semi-revolution about each other. By the terms of the special case in hand, this semi-revolution must be performed in a very few hours. During these few hours the gaseous body (*A*) is undergoing elongation at a rate not much less than that represented by its full explosive competency. The rotational forces are diagrammatically illustrated in Fig. 1, in which the lag is merely estimated and the distortion of *A* is simplified while that of *B* is neglected.

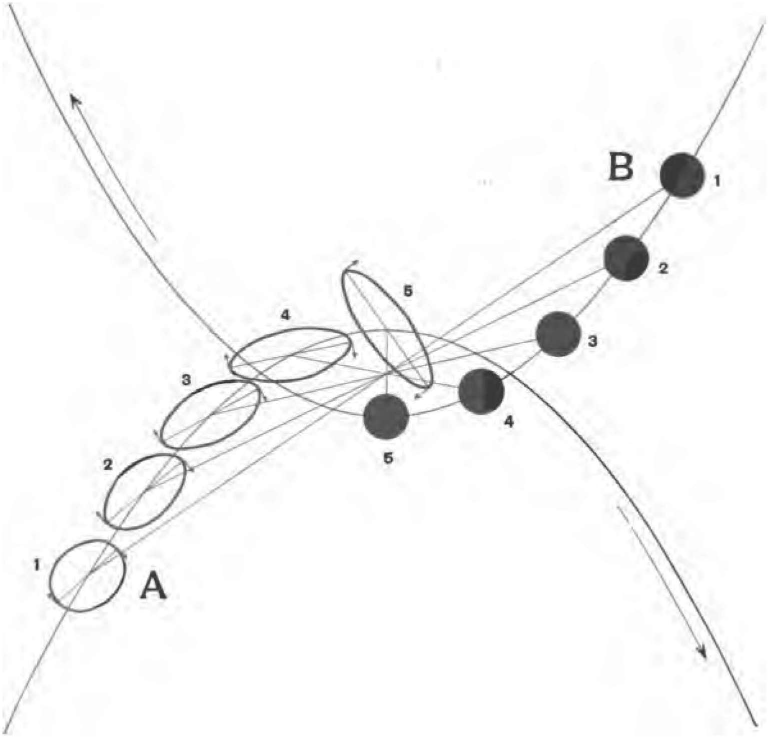


FIG. 1.—Diagram illustrating the elongating and rotatory effects of a solid stellar body, *B*, upon a gaseous sun, *A*, during their mutual approach to periastron. $A^{1, 2, 3, 4, \& 5}$ indicate successive positions, changes of form, and rotation of the gaseous star on its approach to periastron. $B^{1, 2, 3, 4, \& 5}$ represent the successive positions of a solid body of equal mass and velocity which is assumed for convenience to remain intact. Position A^1 corresponds to B^1, A^2 to B^2, etc. The lines joining their centers indicate the successive directions of mutual attraction. The arrows indicate direction of movement.

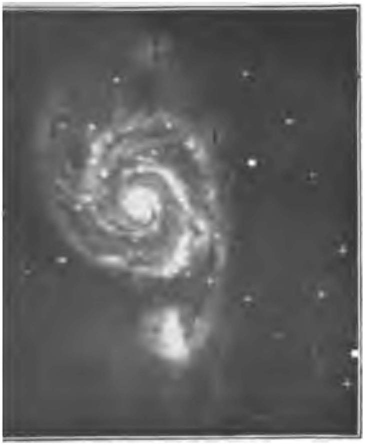
It is assumed that the lag of the axis of elongation of *A* is such that the effective path of explosive projection will be directed to the rear of *B*. It must be noticed that if the center of *A* passes through the outer part of the Roche sphere of *B*, the nearest edge of *A*, if undistorted, would pass within two or three hundred thousand miles of *B*, and hence that the projective elongation of *A* must pass critically near *B;* but the relative speed of the bodies *A* and *B* is so great—both being near the parabolic velocity with respect to the other—that the projected matter of *A* can only collide with *B* on the supposition that the velocity of projection at least equals the parabolic velocity of the body and acts instantaneously, the last of which is impossible. This is based on the assumption that the transverse component of the attraction of *B* prevents the elongation of the minor axis of *A*, which is true of liquid bodies tidally affected, but might perhaps break down in a gaseous body under these extraordinary conditions. The point, however, is not important here, for if the edge of the projected part of *A* collide with *B*, it will only intensify the rotatory effects under consideration, and such collision is contemplated as an essential feature of the next following case, but is excluded here as the effects of *approach without collision* is the special theme under discussion.

The very close approach of the elongated extremity of *A* to *B* obviously gives great effectiveness to the rotatory influence of *B*'s attraction upon it. If the amount of this attraction be represented by the fall of $\frac{1}{1000}$ part of the mass of *A* toward *B* at a mean distance of 200,000 miles from *B*'s surface—the masses of *A* and *B* being each equal to that of the sun—such a fall for about two hours and a half would generate a momentum equal to the whole revolutionary and rotatory momentum of the present solar system. It would appear, therefore, that under the conditions postulated a rotation of a highly effective kind must be imparted to the elongated body. It will now appear that the previous rotatory energy of the sun, which is only about 2 per cent. that of the solar system, is a negligible factor.

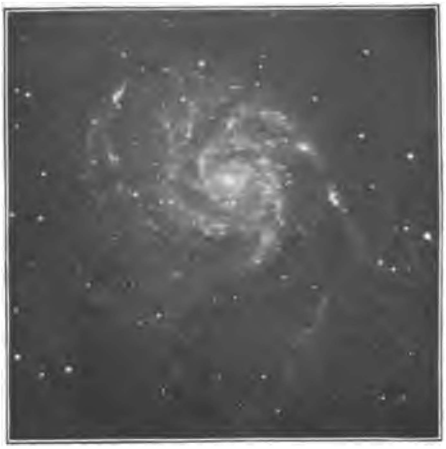
The history of *A* then takes this form: (1) A very rapid elongation in the hour or two preceding its entrance upon the Roche sphere. (2) After entrance upon the Roche sphere, an explosive elongation actuated by the elastic energy then remaining in the body unrestrained by self-gravity in the axis of elongation. (A portion of the original elastic energy had been consumed in the previous elongation and a corresponding amount of momentum had been acquired, the larger component of which would be effective along the changed line of elongation.) (3) After passing out of the Roche sphere, the restraints of gravity begin again to be felt and rapidly increase as *A* and *B* retire from each other, but the distance to which the extremities of *A* have already been projected, and the new relations thereby assumed to the remaining mass of *A*, and to *B*, render the renewed gravitative influence far less effective than the original. and the projection must continue until the momentum acquired is overcome. (4) Coincident with this projection a constantly increasing rotation toward *B* has been generated, which possibly reached an effectiveness comparable to that of the solar system. *The effects of explosive projection combined with concurrent rotation must obviously give rise to a spiral form.*

It seems clear from the nature of the case that there would be a certain brief period when the climax of projective effects would be reached, and that a stream of material of much greater mass and velocity than at other instants would at this time be projected from the extremities of the elongated mass in both directions. There should therefore be two chief arms to the resulting spiral starting from the opposite points of the central mass and extending outward to the limits of the spiral—indeed constituting the most outlying portions of the spiral. These must be curved in a common direction by the rotation of the mass. Such predominant arms are notable features in the typical spiral nebulæ. They are well shown in Nos. 1, 2, 3, 4, 5, and 6, Plate I, all of which are reproductions from photographs furnished by the late Professor Keeler.

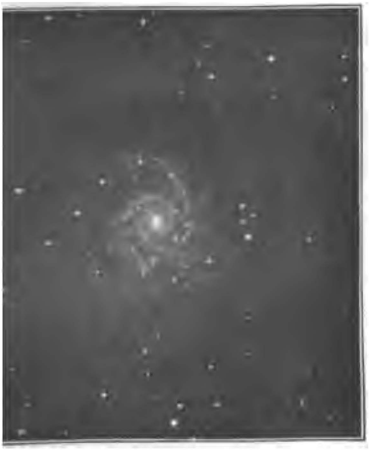
In the illustrative case that has just been discussed the solid body *B* was made to represent a convenient possible case but



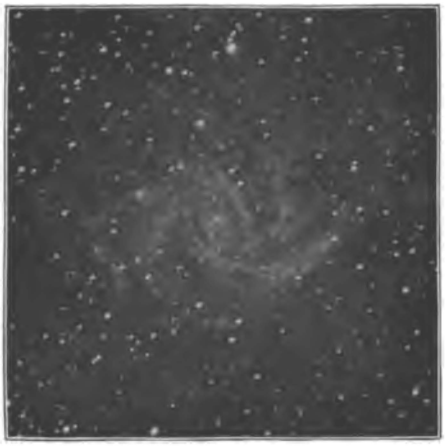
1



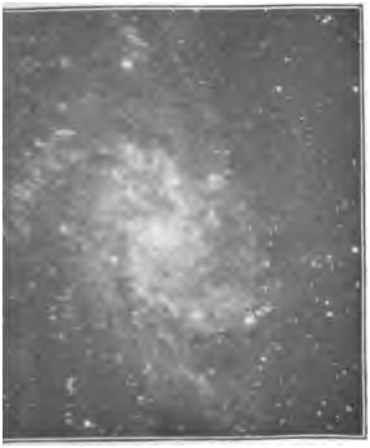
2



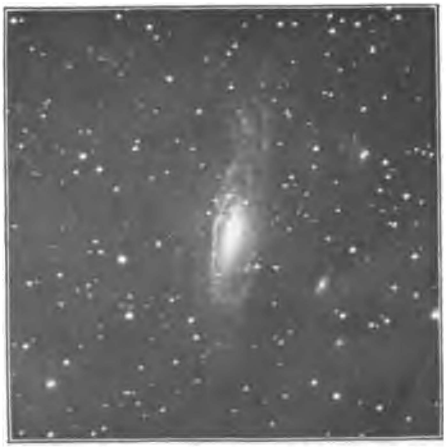
3



4



5



6

SPIRAL NEBULAE

1. *M 51 Can. Ven.*=*G. C. 3572–3574*
2. *M 101 Urs. Maj.*=*G. C. 3770—3771*
3. *M 74 Piscium*=*G. C. 372*
4. *H IV 76 Cephei*=G. C. 4594
5. *H 33 Trianguli*=G. C. 352
6. *H I 53 Pegasi* and her nebula

approach, although it will not necessarily follow, because the planes may not coincide, and for other reasons, may result—if not at once, at least ultimately—as a consequence of the shiftings and modifications which such a disturbed condition involves. For example, it is obvious that by a favorable conjunction with a passing system whose sun is distant from *Neptune* considerably more than the radius of his orbit, there may be an elongation of the orbit of *Neptune* so as to make it cut one or more of the inner orbits, and that further modifications may arise out of these relations which will either increase or decrease the eccentricity. The principles applicable here are identical with those that have been found to produce radical modifications of the orbits of comets and that have been worked out by H. A. Newton and others.

To embrace the full possibilities of the case, it is therefore necessary to consider (1) the effects of systems passing each other at distances varying from those in which the outermost planets do not even cut each other's orbits, down to center-on-center collisions, and (2) to take account of the ulterior effects of disturbed orbits, as well as the immediate effects. This last is a consideration of no small importance in the qualitative as well as the quantitative application of the doctrine, for it distributes the effects over an indefinite period of time, and does not require their coincidence with the passage of the systems. The ulterior effects, so far as the disruption of secondaries is concerned, may apparently be much greater than the immediate effects. If this is not already clear, let a specific case be taken, as, for example, two solar systems passing each other so that their centers shall be 500,000,000 miles apart at nearest approach. If the planes of the systems are transverse to their paths, the ideal undisturbed orbits of the asteroids will touch, or closely approach, or slightly cut each other, as the individual case may be. The ideal orbits of the *Jupiters* will fall but little short of the passing sun, while the ideal orbits of *Saturn*, *Uranus*, and *Neptune* will fall outside the passing sun. While the precise results of such an event cannot be computed, it is quite certain that the secondary systems of the two suns will be most profoundly disturbed and the symmetrical and harmonious relations of the planetary orbits be utterly broken up. While even in this case the *immediate* contingency of a disruptive approach of one secondary to another may not be high, there will arise a *perpetuated series of contingencies*, the consequences of which will apparently be immeasurably greater than those immediately incident to the disturbing action, and the end of this perpetuated series of contingencies can scarcely be foreseen. Assuming that the great planets will exercise the same kind of influence over the small planets and asteroids that pass near them that *Jupiter* does over comets, the range of possible contingencies involves, on the one hand, closer and closer approaches and even collisions with the Sun and with other planets, and, on the other hand, the development of extremely elliptical orbits that will carry the small bodies into the sphere of influence of some other system. How large a proportion of these theoretical possibilities will be realized in a given disturbed system, it is impossible to determine, for the problem is far beyond the power of mathematical analysis, but it seems at least probable that results of moment may ensue.

If we may judge from the solar system, the small bodies may be assumed to be at least fifty times as numerous as the large ones, while not improbably they are a hundred or several hundred times as numerous. Other things being equal, they should show the characteristic effects of the action under discussion with correspondingly greater frequency. But the other conditions intensify these effects. A small body may be disrupted by a large one, but not necessarily the reverse. So, too, a small body may be thrown into an erratic orbit, while the orbit of the large body may not be sensibly affected, as shown by the changes in the orbits of comets caused by *Jupiter*. By far the most common effect of the close approach of two star systems should therefore be the fragmentation of the small bodies by being caused to pass within the spheres of disruption of the large bodies. As previously indicated, *the contingency of acquiring at the same time* *highly erratic orbits is imminent, and these are specially subject to still further changes, and thus these fragmental clusters come to possess by the very circumstances of their birth the second characteristic of comets, as well as the first.*

Whether they would possess at the same time, or come at length to possess, the *third* characteristic of comets, the attenuated matter of which cometic tails are made, is not so clear, since the nature of this matter and its condition are not yet fully known. The recent discoveries relative to the extreme ionization of matter and perhaps even its corpuscular dissociation, and the radio-activity of certain kinds of matter are at least very suggestive in this connection. Six of the elements reported by good authority as detected in meteorites, are known to possess, or to be habitually associated with, radio-active matter, viz., barium, bismuth, cerium, lead, titanium, and uranium. It is not very material here whether this radio-activity is really possessed by all these elements themselves, or simply by substances associated with them. If the coma and tails of comets are dependent on rare substances of a radio-active or extremely volatile nature, and hence permanently retensible only in the interior of bodies, it would be difficult to imagine conditions more favorable for setting them free in unusual volume than minute tidal disruption; particularly is this true if the retention of these substances is dependent on low temperature, as seems to be the case, since they are brought forth and driven away at a highly accelerated rate as the sun is approached. This view seems also to be supported by the fact that comets which remain long in the vicinity of the sun, as for example the short-period comets, lose their tails in a brief period.

If the attenuated cometic matter owes its essential peculiarities to electric states, these might perhaps be derivable from the revolutionary movements of the magnetic elements in the fragmental swarm, for by the hypothesis of tidal disruption the swarm should inherit a rotatory movement, and the fragments should contain both magnetic and magnetizable matter, variously associated with diamagnetic matter.

That short-period comets are subject to progressive disintegration, and that their scattered elements constitute one class of meteorites, is familiar doctrine. There seems no reason for withholding the conception from comets which have parabolic or hyperbolic orbits, for in certain cases such comets have shown signs of disruption and partial dispersion in their perihelion passages. To the dispersed elements of these comets of high velocity is assigned (in part at least) such meteorites as come to earth from diverse directions with velocities incompatible with an origin within the solar system.

It remains to consider whether the fragments derived from the disruption of an asteroid, satellite, or small planet through differential gravitative strain without collision, will satisfy the characteristics which meteorites display. Ample data for a judgment on this vital point will be found in the articles on the structure of meteorites in the first two numbers of the *Journal of Geology* for the current year, by Dr. Farrington, who, at my request, has kindly brought together in succinct and systematic form the essential characteristics of meteoric structure. A study of these characteristics will show that, while they embrace a great and very significant variety, they are all referable to the structures that are appropriate to small planets, while it is difficult to see how all of these characteristics can be found in derivatives from any of the alternative sources to which meteorites have been assigned, namely, volcanic action of the moon or of the planets, explosive projection from the sun, or individual aggregation in space. Some of the matter is fragmentary, implying surface conditions, while some of it is coarsely crystalline, implying deep-seated conditions. Some is volatile and combustible, implying the absence of high temperature throughout its whole antecedent history, while some as distinctly implies the presence of high temperature. In some meteorites the iron is segregated, while in others it is disseminated. Frequent brecciated structures imply fracturing and recementation. *Faulting and slickensides* demonstrate movements attributable to the parent body, but not to the meteorite itself. Veins imply internal transfer and redeposit of molecules. The absence of the oxidation of the iron accords with internal conditions, and also with the supposed absence of atmospheres from small planets, asteroids, and satellites. In short, every feature of the meteorites, save, of course, the external effects of fragmentation and of heating during their fall through the atmosphere, is assignable to small planetary bodies riven into fragments without great heat and, by reason of this, retaining the varied structure attained in the parent body.

As previously indicated, the disruption of a body like the earth, the main mass of which has a temperature much above the melting point of its substances at low pressures, and which is greatly compressed within by self-gravity, would doubtless cause it to burst forth into a luminous body with perhaps some dispersive violence. The progressive stages of distortion which take origin in simple tidal protuberances and grow to greater and greater degrees of deformation and crustal fissuring, until the final stage of disruption is reached, could scarcely fail to bring some parts of the ocean into contact with some parts of the heated interior, with inevitable Krakatoan consequences. Fragments of the crust under these conditions might possibly give origin to meteorites, but the probabilities of such fragments being projected beyond the 640,000 miles of the earth's dominant influence, or beyond the similar spheres of influence of other massive planets, would not seem to be great; and, if realized, the fragments would doubtless be reduced to dust, as in the case of the Krakatoan explosion, and this state of minute division would exclude such meteorites from recognition except as vanishing shooting stars. The probabilities are that the matter of a disrupted earth or a similar massive planet would be again assembled into a planetary body by its strong self-gravity. The phenomenon would therefore be that of a temporary star. Assuming considerable dispersion, it might be rather brilliant for a time, but would rapidly cool as the result of such dispersion, and soon sink into invisibility. In the case of such a body as *Jupiter*, accepting current doctrine as to his nature, the initial brilliancy must be much greater and the cooling to invisibility much more prolonged.[1] To phenomena of this class may perhaps be tentatively assigned certain of the temporary stars. Obviously these can only be such as had no prior visibility, and such as sink sooner or later again into invisibility. Whether this invisibility were due to the superficial cooling of the nucleus, or merely to a deep enshrouding of cooled vapor, would be immaterial.

It has already been indicated that a possible result of the serious disturbance of one solar system by the near transit of another would be a fall of some of the disturbed planets upon one of the suns. This also might be an ulterior rather than an immediate result, through the modifying effects of other planets, as well as the direct effects of the primary disturbance. Such a fall must be presumed to give rise to a notable increase of heat in the central body, as well as to mechanical effects, both of which would be conditioned by the mass and velocity of the secondary. An outburst of greater or less brilliancy must be presumed to be the result. The mechanical effects upon the sun would probably involve great changes in temporary density and condition, as well as outshoots of hot gases in various directions at high velocities. The effects might thus coincide with the phenomena of that class of the temporary stars in which a luminous state precedes and follows the outburst, and in which varying densities or high velocities in opposite directions seem to attend the temporary brilliant stage.

The disruption of suns has been neglected thus far. While, under the terms of the hypothesis, the disruption of these bodies must be rarer events than the fragmentation of the more numerous small bodies, the results must be correspondingly more important, by reason of their magnitude and character.

It has already been observed, in passing, that the internal elasticity of large hot bodies under great self-gravitative compression may so far aid in disruption, by coöperation with the differential gravity of an adjacent body, as to cause dispersion even before the Roche limit is reached. In the case of very large bodies that are already gaseous, such as the sun, this phenomenon gives rise to a special case of extreme interest. Under this special case, there arise a large variety of particular instances due to the varying sizes, velocities, paths, rotations, and constitutions of the couplets of stars concerned, and also to the adventitious effects of their secondaries; but, for a simple illustrative case, let it be assumed that two bodies of equal masses and equal velocities are approaching each other on parabolic paths, and that at periastron they will pass through each other's spheres of disruption, or rather, spheres of dispersion. For convenience, let if be assumed that one of these bodies (*A*, Fig. 1) is gaseous, while the other (*B*) has already become so cold and solid as to act essentially as a unit, though disrupted. The history of the dispersion of the gaseous body may then be followed alone. Let the rate of rotation of the gaseous body (*A*) be relatively low, as in the case of our sun. It may then be neglected in a general discussion, since as a dynamic factor it is trivial compared with the enormous energies of momentum and of elastic dispersion involved. This will appear clear in the outcome. Furthermore, the direction of rotation with reference to the parabolic paths might happen to be any one of an indefinite number, in many of which the effect would be inconsequential, even if the energy were large. In the close approach of these two bodies the two great dynamic factors of special interest are (1) the tidal distortion, and (2) the elastic expansion of the gaseous body.

---

[1] Such a body as *Jupiter* might perhaps, under proper conditions, be dispersed in the same manner as a sun as sketched beyond.

While the two bodies are yet distant from each other, they must begin to take on elongation of the tidal type as the result of their mutual differential attraction, this elongation being aided by the high internal mobility and elasticity of the gaseous body. As the bodies approach periastron, this elongation must progress at an accelerated rate. At the moment of the entrance of the gaseous body *A* upon the Roche sphere of the body *B*, self-gravitation, in accordance with Roche's doctrine, will have been completely neutralized on the lines joining the centers of *A* and *B*, and its restraining influence upon the elasticity of the gaseous body on these lines will have been removed, while the gravitative constraint in the transverse section will be increased. The expansive energy of the compressed gaseous matter will therefore be left to exert its full projectile force in the direction of the axis of elongation. While I am unable to offer a numerical estimate of the magnitude of this expansional energy in such a body as the sun, it is certainly of a high order of magnitude. The speed at which prominences are projected from the sun under present conditions closely approximates to the parabolic velocity with respect to the sun, and this is accomplished in spite of gravitation and a resisting atmosphere.

The case in hand, therefore, starts with simple tidal elongation at a distance, and increases to an explosive maximum as the bodies approach periastron. This increase is at first gradual, but in the last stages of approach to periastron the acceleration is exceedingly rapid. In any attempt to follow the process in more detail, adhering to the recognized principles of tidal action, four particulars are of special moment: (1) the progressive elongation of the body, (2) the change in the direction of tidal distortion, (3) the lag of the line of maximum elongation behind the line of maximum attraction, and (4) the rotatory effects arising from the gravitation of *B* on the tidal protuberances of *A*, which in this case will be peculiarly effective because of the enormous distortion of *A* and the very close proximity of *B* at the critical stages. The principles from which these effects arise are thoroughly demonstrated and are familiar to all students of tidal phenomena, and it is only their special applications to this case that need be discussed. The rotatory effects are a little peculiar in that both of the tidally acting bodies are rapidly approaching each other, and developing extraordinarily powerful differential attractions, while at the same time they are swinging about their common center of gravity. Near periastron they may be regarded as performing a semi-revolution about each other. By the terms of the special case in hand, this semi-revolution must be performed in a very few hours. During these few hours the gaseous body (*A*) is undergoing elongation at a rate not much less than that represented by its full explosive competency. The rotational forces are diagrammatically illustrated in Fig. 1, in which the lag is merely estimated and the distortion of *A* is simplified while that of *B* is neglected.

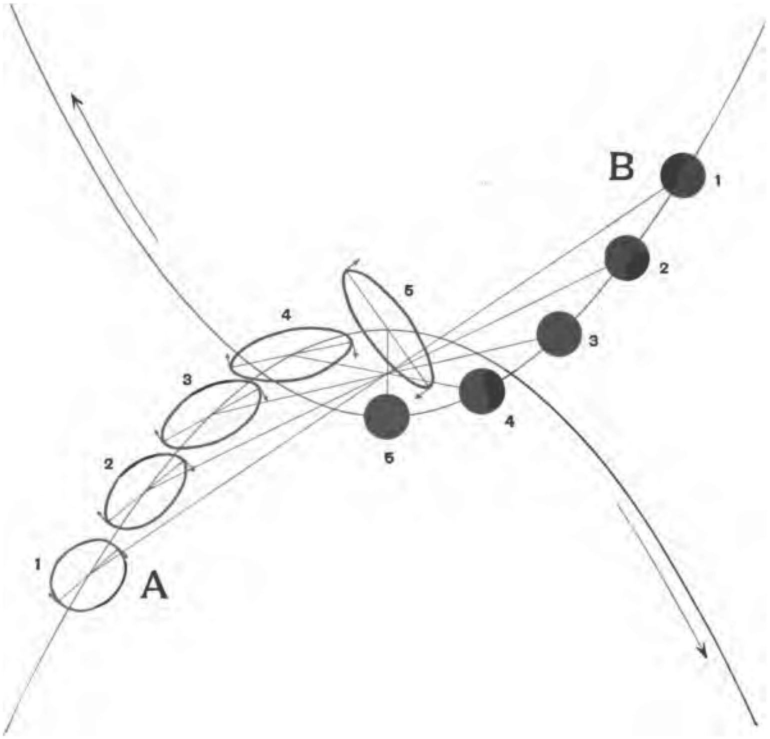


FIG. 1.—Diagram illustrating the elongating and rotatory effects of a solid stellar body, *B*, upon a gaseous sun, *A*, during their mutual approach to periastron. A 1, 2, 3, 4, & 5 indicate successive positions, changes of form, and rotation of the gaseous star on its approach to periastron. *B* 1, 2, 3, 4, & 5 represent the successive positions of a solid body of equal mass and velocity which is assumed for convenience to remain intact. Position *A*1 corresponds to *B*1, *A*2 to *B*2, etc. The lines joining their centers indicate the successive directions of mutual attraction. The arrows indicate direction of movement.

It is assumed that the lag of the axis of elongation of *A* is uch that the effective path of explosive projection will be directed to the rear of *B*. It must be noticed that if the center of *A* passes through the outer part of the Roche sphere of *B*, the nearest edge of *A*, if undistorted, would pass within two or three hundred thousand miles of *B*, and hence that the projective elongation of *A* must pass critically near *B;* but the relative speed of the bodies *A* and *B* is so great—both being near the parabolic velocity with respect to the other—that the projected matter of *A* can only collide with *B* on the supposition that the velocity of projection at least equals the parabolic velocity of the body and acts instantaneously, the last of which is impossible. This is based on the assumption that the transverse component of the attraction of *B* prevents the elongation of the minor axis of *A*, which is true of liquid bodies tidally affected, but might perhaps break down in a gaseous body under these extraordinary conditions. The point, however, is not important here, for if the edge of the projected part of *A* collide with *B*, it will only intensify the rotatory effects under consideration, and such collision is contemplated as an essential feature of the next following case, but is excluded here as the effects of *approach without collision* is the special theme under discussion.

The very close approach of the elongated extremity of *A* to *B* obviously gives great effectiveness to the rotatory influence of *B*'s attraction upon it. If the amount of this attraction be represented by the fall of $\frac{1}{1000}$ part of the mass of *A* toward *B* at a mean distance of 200,000 miles from *B*'s surface—the masses of *A* and *B* being each equal to that of the sun—such a fall for about two hours and a half would generate a momentum equal to the whole revolutionary and rotatory momentum of the present solar system. It would appear, therefore, that under the conditions postulated a rotation of a highly effective kind must be imparted to the elongated body. It will now appear that the previous rotatory energy of the sun, which is only about 2 per cent. that of the solar system, is a negligible factor.

The history of *A* then takes this form: (1) A very rapid nickel present. In hardness and tenacity the nickel-iron of different meteorites varies greatly. That of some meteorites is harder than steel, that of others softer than wrought iron. That of some meteorites is so brittle as to break in pieces with a blow of the hammer, that of others so malleable that it can be worked into implements of various shapes. Nickel-iron is strongly magnetic and some iron meteorites exhibit polarity due perhaps to induction of the magnetism of the earth. The specific gravity of nickel-iron ranges between 7.6 and 7.9. It is dissolved at ordinary temperatures by the common acids, by solutions of copper sulphate, by copper chloride, by mercuric chloride, by bromine water, by copper ammonium chloride, and by a few other reagents. Some masses of nickel-iron when placed in neutral solutions of copper sulphate reduce the latter, while others do not. The former are known, according to the terms first used by Wöhler, as active, the latter as passive irons. Nickel-iron oxidizes rapidly when exposed to the atmosphere, the rapidity decreasing, however, with increase in the percentage of nickel. In regard to the manner of occurrence of the nickel-iron it may be noted that in the iron meteorites it forms a compact mass except in so far as it is interrupted by inclusions of other minerals. In the iron-stone meteorites all gradations occur from a continuous network to isolated grains. In the stone meteorites it is present in the latter form. A more or less lineal arrangement of these grains, recalling Widmanstätten figures, is often observed in the stone meteorites. When the substance occurs in grains, whether large or small, the shape of these is usually very uneven, being sometimes more or less rounded but generally irregularly branching. Sometimes regular forms such as cubes and octahedrons may be observed. In the Ochansk meteorite, von Siemaschko observed actual crystals made up of a combination of the cube, octahedron, dodecahedron, and a tetrahexahedron. Other cuboidal forms have been observed. The two or possibly three subordinate alloys (kamacite, taenite, and plessite) of which nickel-iron is composed have been described in a previous article and their composition given.

Chrysolite.—This is, next to nickel-iron, the chief mineral constituent of meteorites. It is found in all the iron-stone and nearly all the stone meteorites and makes up a large part of their mass. It occurs as crystals and as rounded and angular grains. In the group of iron-stone meteorites known as pallasites it is porphyritically developed in the nickel-iron; in other iron-stone meteorites it forms together with pyroxene a granular aggregate filling the meshes of a network of nickel-iron. In the chondritic meteorites the manner of its occurrence has already been described. Crystals occurring in cavities or isolated by dissolving adjacent nickel-iron lend themselves readily to goniometric measurement. A total of twenty forms, similar to those found on terrestrial chrysolite has thus been identified. The color of the mineral is usually the typical olive-green of terrestrial chrysolite but may vary to honey-yellow or red. Much of the meteoritic chrysolite is characterized by an abundance of opaque inclusions often regularly arranged. Intergrowths with a colorless to dark brown glass are also common, especially in the chrysolite of chondritic meteorites. Gas pores are rare. Alteration products so common to terrestrial chrysolite are entirely lacking. Much of the chrysolite shows a strong tendency to fissuring, especially in thin sections. Well-marked cleavage is not common. Numerous analyses of mechanically separated chrysolite show a composition similar to that of the terrestrial mineral. The percentage of Fe in these analyses shows variations from about 10 per cent. to about 30 per cent. One feature of the composition of meteoric chrysolite which seems at first difficult to account for, is an almost entire lack of nickel oxide. This, as is well known, is a very constant constituent of terrestrial chrysolite. Daubrée has shown, however, that an absence of nickel from meteoritic chrysolite should be expected, since nickel has less affinity for oxygen than iron and would not be attacked until the latter was completely oxidized. While terrestrial iron has been completely oxidized that of meteorites has not. The correctness of this explanation has further been shown experimentally by fusing terrestrial chrysolite with pyroxene in the presence of a reducing agent. The nickel of the chrysolite then formed an alloy with the iron of the pyroxene. The siliceous portion of meteorites that is soluble in hydrochloric acid may for the most part be considered chrysolite, since numerous analyses of this portion give results corresponding in composition to this mineral.

Orthorhombic pyroxenes.—The minerals of this group are next in abundance to chrysolite as a constituent of meteorites. They form an essential part of nearly all stone meteorites and are not lacking in the iron-stone meteorites. At least four meteorites consist of orthorhombic pyroxenes alone. These are the meteorite of Bishopville, practically composed of enstatite alone, and those of Manegaon, Ibbenbühren and Shalka, which consist essentially of hypersthene. The color of the orthorhombic pyroxenes varies from colorless through white to various shades of green. Often the mineral has the typical color of chrysolite. In thin section the pyroxene is colorless to slightly colored. Its habit is usually prismatic but it may also occur as rounded grains. Crystals with well defined planes have been observed in the Breitenbach, Bustee, Manegaon and other meteorites. A total of thirty-two forms has thus been identified and the axial relations found to correspond with those of terrestrial hypersthene. Prismatic, macrodiagonal and brachydiagonal cleavages are recognizable. It is especially characteristic of the mineral to form eccentric, radiating, polysomatic chondri, the structure of which has been described in a previous article.

Numerous chemical analyses of mechanically separated orthorhombic pyroxenes have been made. These show all gradations between the compositions represented by the formulas $MgSiO_3$ (enstatite) $(Mg, Fe) SiO_3$ (bronzite) and $(Fe, Mg) SiO_3$ (hypersthene). The portion insoluble in acids, of meteorites consisting essentially of nickel-iron, chrysolite and orthorhombic pyroxenes, may be considered to be essentially the latter, as shown by numerous analyses which give results corresponding with the pyroxene formula. The orthorhombic pyroxenes of meteorites are thus seen to be entirely comparable to the terrestrial minerals of the same name.

Monoclinic pyroxenes.—Two kinds of monoclinic pyroxenes have been identified in meteorites, the first bearing iron and alumina, the second free from alumina and nearly free from iron. The first may be considered similar to terrestrial augite, the second to terrestrial diopside. Augite has been identified in many meteorites, diopside positively only in one. Crystals of meteoritic augite have been measured goniometrically and eight forms similar to those of terrestrial augite found. As a rule, however, the augite occurs as grains or splinters. It varies from brown to green in color, in some meteorites is pleochroic in thin section in others not at all. Parting parallel to the base, owing to repeated twinning, is common and characteristic. It is sometimes regularly intergrown with orthorhombic pyroxene. Inclusions of glass and black dust are common. Pyroxene resembling diopside was identified by Maskelyne in the Bustee meteorite. It occurred in grains and splinters and was of a gray to violet color. A few goniometric measurements were possible. Analysis showed the composition to be that of a calcium-magnesium pyroxene. Crystals and grains from a few other meteorites may perhaps be referred to diopside but the determination is not certain.

Plagioclase.—Of the minerals of the feldspar group, anorthite may be mentioned as forming an essential constituent of the classes of stone meteorites known as eukrites and howardites and as occurring in others. It forms according to Rammelsberg about 35 per cent. of the stones of Juvinas and Stannern. Of the other members of the plagioclase series, albite, oligoclase and labradorite have been reported in single meteorites, but in most cases where plagioclase has been found the species has not been determined. Orthoclase has not yet been identified in any meteorite. Crystals of anthortite from the Jonzac meteorite reach a length of 1^{cm}. From the druses of the Juvinas meteorite anorthite crystals were obtained which served for goniometric measurement, eight forms being thus identified. Some anorthite crystals show twinning according to the Carlsbad law and in the Llano del Inca and Dona Inez meteorites twins according to the albite and pericline laws were found. The mineral is sometimes white and sometimes colorless and in luster varies from dull to vitreous. Inclusions nearly always abound and they are generally regularly arranged. The inclusions are chiefly colorless glass, but sometimes brownish glass and opaque grains occur. Analyses of mechanically isolated anorthite have been made which show a composition similar to that of terrestrial anorthite. CaO amounts to about 18 per cent. in these analyses.

Calculating from analyses Tschermak concludes the feldspar of the stone of Gopalpur to be oligoclase, Lindstrom that of Hessle to be the same and Schilling that of Tennasilm to be labradorite. The presence of plagioclase other than anorthite has been proved by microscopical and chemical examination of other meteorites, but the species have rarely been determined. Such feldspars occur as lath-shaped individuals and as grains and splinters. Inclusions are much less common than in anorthite. Rounded, elongated inclusions referred by Tschermak to chrysolite and bronzite are, however, quite characteristic. Gas inclusions seem to be more abundant in the feldspars of meteorites than in any other constituent, though even here they are rare.

Maskelynite.—This is an isotropic, colorless, though becoming milky through alteration, transparent mineral of vitreous luster and conchoidal fracture. Its hardness is somewhat over 6; specific gravity 2.65. It has no cleavage but shows occasional irregular cracks and striæ similar to those of plagioclase. Inclusions of magnetite and augite are arranged in apparent zones. The mineral is slightly decomposed by hydrochloric acid. Thin splinters fuse, but with difficulty. Lath-shaped individuals with rectangular outlines occur, but in most meteorites the mineral is present as minute grains. It forms 22½ per cent. of the meteorite of Shergotty, the remainder of the meteorite being augite and magnetite. It is also an accessory constitutent in the meteorites of Chateau Renard, Alfianello, Milena, Mocs, and others. Its composition is about that of labradorite. Tschermak regards the mineral as a fused feldspar, while Groth and Brezina consider it a distinct species allied to leucite. Its straight, sharply defined outlines, the existence of striæ, and the absence of any fused appearance make Tschermak's view difficult to accept, though the mineral resembles the feldspars in so many other respects.

Included gases.—All meteorites which have so far been tested give off on heating one or more of the following gases: Hydrogen, carbon monoxide, carbon dioxide, nitrogen, and marsh gas. Comparing the iron meteorites with the stone meteorites in regard to the kind of gases given off it is found that the former are characterized by a high content of H and CO, the latter by an excess of CO_2. The following table of analyses of gases from eight iron and six stone meteorites, quoted from Cohen, gives an idea of the relative quantity of each gas:

	H	CO	CO_2	N	CH_4
Iron meteorites	63.09	20.70	8.12	7.52	0.57
Stone meteorites	17.55	4.15	71.66	2.20	4.17

The volumes of the gases obtained vary from 0.97 of a volume given off from the iron of Shingle Springs to 47.13 volumes collected from the Magura iron. The average number of volumes obtained from the meteorites quoted in the above table is 2.82. The gases in meteorites appear therefore to be under a somewhat greater pressure than that of the earth's atmosphere. It has often been urged that the gases obtained from meteorites by the methods above mentioned may have been absorbed from our own atmosphere. It is known on the one hand that terrestrial rocks give off on treatment gases very similar in kind and quantity to those obtained from meteorites. Thus Wright obtained from one ordinary trap rock ¾ of a volume of gas, 13 per cent. of which was CO_2 and the remainder chiefly hydrogen, and from another, one volume of gas containing 24 per cent. CO_2 and the remainder chiefly hydrogen. Tilden has also recently shown that "the crystalline rocks of the surface of the earth contain very notable quantities of gas, consisting of hydrogen in preponderance, carbon dioxide, and carbon monoxide in large percentage, and nitrogen and marsh gas in small quantities, with water vapor, but with a practical absence of oxygen. Twenty-five analyses including ancient and modern volcanic and even some metamorphic rocks gave an average volume of gas equal to about four and one half times the volumes of the containing rocks."[1] Further, it is urged that no meteorites have been analyzed as to their gases immediately after their fall. In contrast to these facts it should be noted that the Homestead meteorite was analyzed for gases by Wright within three months from the time of its fall. A second analysis was made a year later in order to test the influence of the earth's atmosphere upon the stone. It was found that very little change had taken place except a slight *loss* of carbonic acid. Ansdell and Dewar in testing the gases of the Pultusk and Mocs meteorites chose stones of those falls which were completely incrusted so that the chances of absorption of gases from the earth's atmosphere might be reduced to a minimum. Yet the results obtained accorded well with those from other meteoric stones and for Pultusk the percentages were remarkably like those derived by Wright in a previous and independent examination of stones of the same fall. There seems, therefore, good reason to believe that the gases obtained from meteorites are brought with them from space and that they have not been derived from the earth's atmosphere.

How the gases are held by the meteorites is uncertain. Wright was inclined to believe that the pores occasionally noted in the silicates of meteorites indicated cavities where the gas was held. Such pores are of too rare occurrence, however, to meet the demands of the problem. The phenomenon seems more like the occlusion of hydrogen by platinum or zinc, and the gases are probably held partly in the intermolecular spaces and partly chemically united. Travers, however, regards them as produced by heat from the non-gaseous elements of the meteorites.[1] The magnetic and nonmagnetic or, in other words, the metallic and stony portions of the Homestead meteorite were tested separately by Wright in order to determine whether these different portions exercised any selective action in holding gases. The investigation gave the following results :

---

[1] T. C. CHAMBERLIN: JOUR. GEOL., Vol. VII, p. 558. Quoted from Chemical News, April 9, 1897.

	Volumes	H	$CO+CO_2$	N
Entire stone	1.87	50.93	48.07	1.00
Magnetic portion, 0.51	1.48	59.38	38.72	1.90
Non-magnetic portion, 0.97		30.96	66.96	2.08

The results show no important differences in the gases held by the different portions. By way of caution, attention should be called to the fact that the gases in meteorites may not have been originally present in the form and quantities which the analyses indicate. Thus Wright in making his analyses found CO_2 rapidly reduced to CO through contact with heated iron. Likewise, H, CO, and iron may at a moderate heat reduce the iron oxide present in many meteorites, and thus the character of each be changed. The percentages of the different gases obtained by analyses may be, therefore, more indicative than absolute.

Cohen calls attention to the fact that from artificial irons may be obtained gases corresponding both qualitatively and quantitatively to those obtained from meteoric irons. The following list of analyses illustrates this.

	H	CO	CO_2	N
White, carbonaceous cast iron	74.07	16.76	3.59	5.58
Mild steel	52.6	24.3	16.55	6.5
Ordinary gray massive charcoal iron	38.60	49.20		12.20
Gray coke iron	33.70	57.90		8.40
Steel	22.27	63.65	2.27	11.36

Finally it should be noted that, according to the investigations of Vogel, Wright, and Lockyer, the spectra of the gases obtained from meteorites show remarkable resemblances to the spectra of comets.

---

[1] Proc. Roy. Soc., Vol. LXIV, pp. 130–142.

Iron sulphide.—Troilite-pyrrhotite.—The exact form and composition of the iron sulphide which is a common ingredient in meteorites is a question not yet satisfactorily answered. For convenience, Rose's assumption that the iron sulphide of iron meteorites is troilite, that of stone meteorites pyrrhotite, is usually followed, but there are many occurrences which do not harmonize with this view.

The iron sulphide known as troilite is usually found massive, though crystals have been observed which have been referred by Brezina to the hexagonal and by Linck to the isometric system. The color varies from bronze-yellow to tomback-brown. Streak black. Hardness, 4. Specific gravity, 4.68–4.82. Generally found to be non-magnetic, although magnetic troilite has been reported. Cohen suggests that the magnetism may be due to included nickel-iron. The mineral fuses in the reducing flame to a black, magnetic globule. Decomposed by hydrochloric acid with evolution of hydrogen sulphide, but without separation of sulphur. Not affected by copper sulphate or fuming nitric acid. These reagents may be used, therefore, for its separation.

Most analyses show a composition approximating very closely to FeS. Meunier, however, obtained results more nearly in accord with the formula $Fe_{11}S_{12}$. As this is the composition of pyrrhotite he regards the two as identical. The specific gravities which he obtained, however, correspond to those observed by others for troilite, and there seems therefore, some reason to doubt the correctness of his analysis.

Troilite is almost universally present in the iron meteorites. It may be very unequally distributed in a single mass, however, being abundant in some portions and lacking in others. It usually occurs in the form of nodules, but also as plates and lamellae. The nodules vary greatly in shape and size. Rounded and oval forms are common, as are also lens and dumb-bell shapes. In Carlton a star-like form occurs. Smith separated from the Cosby's Creek iron a nodule weighing 200 grams, while one from the Magura iron measured 13^{cm} in diameter. When troilite occurs as lamellae, these are often regularly arranged parallel to the planes of a cube. Lamellae having this arrangement are known as Reichenbach lamellae. Individual lamellae of this sort average from $0.1–0.2^{mm}$ in width and $1\frac{1}{2}–3\frac{1}{2}^{cm}$ in length. They cross layers of kamacite, and hence must have formed before these. Troilite often occurs intergrown with schreibersite and graphite, and these sometimes surround it. It also often includes nickel-iron.

The fusion and dissipation of troilite nodules during the passage of a meteorite through the atmosphere is a cause of the depressions often to be observed on the surface of both iron and stone meteorites.

The iron sulphide of the stone meteorites occurs chiefly as grains, sometimes as plates, and sometimes in vein-like forms. As mentioned in a previous article, it also occurs in chondri, frequently forming their periphery, while at other times it is in the form of grains. Crystals from the druses of the Juvinas meteorite measured by Rose proved to be hexagonal and to have forms similar to those of terrestrial pyrrhotite. It is largely on account of these observations that the iron sulphide of stone meteorites is considered to be pyrrhotite. On the other hand, the iron sulphide of stone meteorites differs from pyrrhotite in being, for the most part, non-magnetic, and in giving no free sulphur on decomposition with hydrochloric acid. Further, most analyses show a composition corresponding to the formula FeS.

Schreibersite.—This mineral, peculiar to meteorites (if its possible occurrence in the terrestrial iron of Greenland be excepted) is also one of their most remarkable constituents, since it gives proof that the meteorites in which it occurs could not have been exposed for any long time to the action of free oxygen. The mineral is a phosphide of iron, nickel, and cobalt, having the general formula $(Fe, Ni, Co)_3 P$, though the relative proportions of the metals vary. The normal color is tin-white, but this may readily alter to bronze-yellow or steel-gray on exposure to the air. Hardness 6.5, specific gravity 6.3–7.28. Strongly magnetic, and when magnetized retains its magnetism for a long time. Very brittle, being thus distinguished from taenite, with which it is often confounded. Another property which distinguishes it from taenite and from cohenite is that it is insoluble in copper-ammonium chloride. It is soluble in ordinary dilute acids and in acetic acid. Does not reduce copper from a copper sulphate solution. Easily fusible before the blowpipe to a magnetic globule. It occurs as crystals, flakes, foliae, grains, and as needles. In the latter form it was long regarded a separate mineral, and was known under the name of rhabdite, but the identity of rhabdite and schreibersite has been proved by Cohen. The needles and plates often exhibit angular outlines. Individual masses of the mineral often reach a considerable size, one from the Carlton iron being 14 ^{cm}. in length. The mineral also forms a considerable portion of the mass of some meteorites, such as Bella Roca, Primitiva, and Tombigbee River. It is the most widely distributed constituent of iron meteorites, aside from nickel iron, and is believed to be usually associated with the latter mineral in the stone meteorites, though its quantity is so small that it has not often been determined. The small percentage of phosphorus usually found in the analysis of stone meteorites is generally referred to this mineral. Schreibersite has been reported in the terrestrial iron of Greenland, but its presence is not proved. Phosphides similar to schreibersite have been made in several ways artificially. The process followed has been essentially to heat iron to a high temperature together with a phosphorus-bearing compound.

Graphite.—This substance occurs in grains of sufficient size for ready examination only in the meteoric irons. In these it is usually in the form of nodules but sometimes occurs in plates or grains. The nodules often reach considerable size. One nodule taken from the Cosby's Creek iron is as large as an ordinary pear and weighs 92 grams. Even larger ones were found in the Magura iron. Toluca, Cranbourne, Chulafinnee and Mazapil are other irons which contain considerable graphite. Graphite has been estimated to form 1.17 per cent. of the mass of

Magura and 0.8 per cent. of the Cosby's Creek iron. The mineral is usually associated with iron sulphide. With this it may be intimately intergrown or the one may enclose the other. Its texture is compact rather than foliated. Smith found that the meteoric graphite oxidized much more rapidly than terrestrial graphite on treatment with nitric acid and chlorate of potash. This feature distinguishes it from the amorphous carbon separated from cast iron. The meteoritic graphite is also very pure. Although occurring in nodules of the size described, which must have segregated from the surrounding mass, the ash amounted, in an analysis made by Smith, to only 1 per cent. By ether was extracted a small quantity of a substance made up of sulphur and a hydro-carbon, which constituted the only other impurity. Emphasizing the differences between meteoritic and terrestrial graphite Smith was inclined to believe that the graphite of meteorites must have been formed by the action of bi-sulphide of carbon upon incandescent iron rather than that it was analogous in its origin to terrestrial graphite. Ansdell and Dewar, however, concluded from elaborate comparisons of meteoric and terrestrial graphite that they were similar in origin, and were formed by the action of water, gases and other agents on metal carbides. Whatever its mode of formation the occurrence of graphite in meteorites is of geological interest as proving that graphite may be formed in nature without the agency of life.

Cohenite.—This is a carbide of iron, nickel and cobalt. It has been positively identified in only a few meteorites but is doubtless of common occurrence. Its formula is $(Fe, Ni, Co)_3 C$. The mineral is of metallic luster and tin-white color, though readily tarnishing to bronze-yellow. Hardness, 5.5–6. Specific gravity, 7.23–7.24. Strongly magnetic; very brittle. Insoluble in dilute hydrochloric acid and decomposed by concentrated hydrochloric acid only with difficulty. Easily soluble in copper-ammonium chloride. It occurs as isolated crystals on which several forms of the isometric system have been noted; also as grains. Elongated crystals, reaching a length of 8^{mm} are nickel present. In hardness and tenacity the nickel-iron of different meteorites varies greatly. That of some meteorites is harder than steel, that of others softer than wrought iron. That of some meteorites is so brittle as to break in pieces with a blow of the hammer, that of others so malleable that it can be worked into implements of various shapes. Nickel-iron is strongly magnetic and some iron meteorites exhibit polarity due perhaps to induction of the magnetism of the earth. The specific gravity of nickel-iron ranges between 7.6 and 7.9. It is dissolved at ordinary temperatures by the common acids, by solutions of copper sulphate, by copper chloride, by mercuric chloride, by bromine water, by copper ammonium chloride, and by a few other reagents. Some masses of nickel-iron when placed in neutral solutions of copper sulphate reduce the latter, while others do not. The former are known, according to the terms first used by Wöhler, as active, the latter as passive irons. Nickel-iron oxidizes rapidly when exposed to the atmosphere, the rapidity decreasing, however, with increase in the percentage of nickel. In regard to the manner of occurrence of the nickel-iron it may be noted that in the iron meteorites it forms a compact mass except in so far as it is interrupted by inclusions of other minerals. In the iron-stone meteorites all gradations occur from a continuous network to isolated grains. In the stone meteorites it is present in the latter form. A more or less lineal arrangement of these grains, recalling Widmanstätten figures, is often observed in the stone meteorites. When the substance occurs in grains, whether large or small, the shape of these is usually very uneven, being sometimes more or less rounded but generally irregularly branching. Sometimes regular forms such as cubes and octahedrons may be observed. In the Ochansk meteorite, von Siemaschko observed actual crystals made up of a combination of the cube, octahedron, dodecahedron, and a tetrahexahedron. Other cuboidal forms have been observed. The two or possibly three subordinate alloys (kamacite, taenite, and plessite) of which nickel-iron is composed have been described in a previous article and their composition given.

Chrysolite.—This is, next to nickel-iron, the chief mineral constituent of meteorites. It is found in all the iron-stone and nearly all the stone meteorites and makes up a large part of their mass. It occurs as crystals and as rounded and angular grains. In the group of iron-stone meteorites known as pallasites it is porphyritically developed in the nickel-iron; in other iron-stone meteorites it forms together with pyroxene a granular aggregate filling the meshes of a network of nickel-iron. In the chondritic meteorites the manner of its occurrence has already been described. Crystals occurring in cavities or isolated by dissolving adjacent nickel-iron lend themselves readily to goniometric measurement. A total of twenty forms, similar to those found on terrestrial chrysolite has thus been identified. The color of the mineral is usually the typical olive-green of terrestrial chrysolite but may vary to honey-yellow or red. Much of the meteoritic chrysolite is characterized by an abundance of opaque inclusions often regularly arranged. Intergrowths with a colorless to dark brown glass are also common, especially in the chrysolite of chondritic meteorites. Gas pores are rare. Alteration products so common to terrestrial chrysolite are entirely lacking. Much of the chrysolite shows a strong tendency to fissuring, especially in thin sections. Well-marked cleavage is not common. Numerous analyses of mechanically separated chrysolite show a composition similar to that of the terrestrial mineral. The percentage of Fe in these analyses shows variations from about 10 per cent. to about 30 per cent. One feature of the composition of meteoric chrysolite which seems at first difficult to account for, is an almost entire lack of nickel oxide. This, as is well known, is a very constant constituent of terrestrial chrysolite. Daubrée has shown, however, that an absence of nickel from meteoritic chrysolite should be expected, since nickel has less affinity for oxygen than iron and would not be attacked until the latter was completely oxidized. While terrestrial iron has been completely oxidized that of meteorites has not. The correctness of this explanation has further been shown experimentally by fusing terrestrial chrysolite with pyroxene in kindly placed at his disposal, and has recently been published under the auspices of the state survey.

THICKNESS

The strata covering Allegany county have a thickness varying from about 13,300 to 16,000 feet. This thickness is divided between the four geological systems represented in the county in the following manner: Silurian, from 2200 to 2400 feet; Devonian, 7875 to 10,200 feet; Carboniferous, 2825 to 3000 feet, and Permian (?), about 400 feet.

SILURIAN STRATA

Juniata formation.—The oldest rocks outcropping in Allegany county belong in this formation, and are shown in only one locality. This outcrop forms the lower part of the cliffs in the gorge known as "the Narrows" just northwest of Cumberland, where Wills Creek has cut a deep and narrow trench through Wills Mountain. This gorge presents an admirable example of a narrow transverse valley where a stream has cut through a mountain ridge, and this locality has a justly deserved reputation for great natural beauty. The upper 370 feet of the formation is well shown on the northern side of the creek; but in many places in the gorge it is concealed for the most part by heavy talus of white quartzite blocks from the cliff above. In the Narrows 550 feet of the Juniata are shown, but no fossils have been found at this locality. The formation is composed of alternating beds of deep red shales and sandstones which have no regularity of succession, but show a much greater total thickness of shales than sandstones. The sandstones are hard, fine-grained, cross-bedded, and micaceous, some of the strata a foot or more in thickness, but usually less than six inches. The shales are micaceous, weathering readily, and the beds vary from an inch to six feet or more in thickness. This formation was named from the Juniata River, Pa., though in the earlier reports of that state it was termed the Medina or Levant red sandstone (No. IV*b*). It probably represents the older part of the Medina stage of New York near the base of the Upper Silurian, which, in western New York, is composed mainly of red shales.

Tuscarora formation.—This quartzitic sandstone, which rests conformably upon the Juniata formation, and forms the beautiful flat-topped arch of Wills Mountain is admirably shown on its western side, especially at the entrance to the Narrows, and in the upper part of the high massive cliffs bordering the gorge. It also forms the greater part of the exposed rocks in Evitt's and Tussey's mountains and two small areas along the Baltimore and Ohio Railroad near Potomac Station. The formation is a white to light gray, very hard quartzose sandstone composed of fairly coarse quartz grains cemented by siliceous material. Small pebbles of quartz and also those of yellowish-green hard clay occasionally occur. The layers are frequently very massive and cross-bedded structure is not infrequent. Its thickness varies from 250 to 300 feet, and it furnishes building stone and ballast. *Arthrophycus harlani*, a sea-weed, the only fossil found in this sandstone in the county is fairly common on the upper surfaces of the higher beds in the Narrows.

The Tuscarora formation, named from Tuscarora Mountain in Pennsylvania, was formerly called the Medina or Levant white sandstone (No. IV*c*), and represents the upper part of the Medina stage of New York. The Juniata and Tuscarora formations are probably equivalent to the Medina formation of New York, but in western New York, where it is typically represented, especially in the Niagara region, there is not such a definite separation into a lower divison composed of red shales and sandstones and an upper one composed of a white quartzose sandstone as in Maryland. In the Niagara region the Medina is composed of the following divisions named in ascending order: Lower Medina, composed of red shales only about the upper 115 feet of which is exposed in outcrop. Upper Medina, composed of seven zones: (1) 25 feet of gray quartzose sandstone; (2) 25 feet of thin gray shales; (3) five feet of gray sandstones and sandy shales; (4) 6 feet of mainly gray argillaceous shales which become reddish at the top; (5) 35 to 40 feet of mainly thin-bedded sandstone reddish in color or gray mottled with red; (6) 12 to 15 feet of massive sandstone in beds from one to several feet in thickness and varying in color from reddish to grayish; (7) at the top 7½ feet of a hard massive-bedded and compact white quartzose sandstone similar to No. 1. In some thin sandstones in the upper part of No. 6 occurs the characteristic Medina fossil known as *Arthrophycus harlani* (Conrad).[1]

Clinton formation.—The largest area of this formation flanks both sides of Wills Mountain extending to the Potomac River, while two other areas flank the southern ends of Evitt's and Tussey's mountains. The formation is composed largely of yellowish-green to reddish shales, but on weathering, the flat surfaces frequently have a scarlet tint. There are blackish shales and thin fossiliferous limestones in its upper part as well as a greenish-gray to reddish sandstone. The most important lithologic character of the formation, however, is the two beds of iron ore, the lower occurring from 120 to 160 feet above its base and consisting of two strata of iron ore separated by a band of greenish-yellow shales from 6 inches to 6 feet thick. The two ore-bearing strata have a thickness of from 10 to 12 feet. At Cumberland the upper bed of iron ore is 270 feet above the lower one, in the midst of a brownish, calcareous sandstone, nearly 3 feet thick which is directly above a massive 5-foot sandstone stratum. There are 9 inches of quite clear, fossiliferous iron ore and the overlying greenish shales and thin bands of bluish limestone also contain fossils. The thickness of the formation varies from 550 to 600 feet. Fossils are common in the middle and upper portions, some of the species being identical with those of the New York Clinton. The name is derived from the exposures at Clinton, Oneida county, N. Y., where the beds of iron ore have been mined for many years, and the stage is identical with No. V*a* of the Pennsylvania survey which is called the Rockwood formation in the Piedmont folio of the U. S. Geological Survey.

---

[1] For an excellent account of the Medina formation along the Niagara River, see Bull. N. Y. State Museum, No. 45, 1901, pp. 87–95 and accompanying geological map by Dr. Amadeus W. Grabau.

Niagara formation.—This formation surrounds the three areas mentioned under the Clinton formation. The lower part consists of thin-bedded, blue limestones with thin shale partings; but in the upper part the shales predominate and become blackish in color. The thickness varies from less than 250 to fully 300 feet. The thin limestones contain brachiopods and other fossils, some of which are specifically identical with the Niagara fossils. The formation is named from the admirable exposures at Niagara Falls and represents No. V*b* of the Pennsylvania survey and the lower part of the Lewistown formation of the Piedmont folio. The revised classification of the New York series by Messrs. Clarke and Schuchert, however, drops the Niagara formation or group and returns to the earlier classification of Rochester shale, Lockport limestone, and Guelph dolomite.[1]

There has been more or less uncertainty regarding the identification of the Niagara limestone south of New York; but recently Dr. Weller has conclusively shown that the Decker Ferry formation of western New Jersey and eastern Pennsylvania is of the same age "as the Rochester shale and Lockport limestone of Clarke and Schuchert, or as the Niagara formation of most authors."[2] A small collection of fossils from the beds near Cumberland was submitted to Dr. Weller who kindly examined them and wrote that his impression is that they are the same as the Decker Ferry formation, and in New Jersey there are sufficient authentic Niagaran species to definitely refer the formation to the Niagaran. In conclusion he stated that "I should think you would be fully justified in considering the Cumberland fauna as of Niagaran age."[3] Mr. Schuchert has studied these beds in the field as well as their fossils and he positively correlates them with the Niagara. His statement is that

---

[1] Science, N. S., Vol. X, 1899, p. 876.

[2] Geol. Surv. N. J., Ann. Rept. for 1899–1900, p. 18, and also see p. 20.

[3] Letter of May 29, 1901.

"there are beds at Cumberland, Md., holding a fauna of the age between the Lockport [Rochester?] shale and the Guelph of New York and Ontario. This fauna has its peculiarities, but the aspect is certainly not Clinton."[1]

Salina formation.—This formation borders the Niagara but the rocks are largely concealed over most of the areas except along Wills Creek in Cumberland, Flintstone Creek at Flintstone, and the Baltimore and Ohio Railroad near Potomac Station, where one finds the best exposure. In the Potomac section there are four cement beds which have great economic value, the lowest one situated about twenty-five feet above the base of the formation. Fifty feet of the succeeding 140 feet of the formation is composed of the four cement beds which are separated by shales and impure limestones. Succeeding the upper cement bed are 450 feet or more of gray shales, drab and blue limestones and sandstone, the limestones predominating.[2] The thickness is about 700 feet. Fossils are not common. The formation was named from Salina in central New York and is represented by No, V*c* of the Pennsylvania survey and the second part of the Lewistown formation of the Piedmont folio.

The statement has been made that "the geological reader will wonder on what basis the name Salina is applied to the rocks so described" in Maryland.[3] It is perhaps sufficient to state that Professor Lesley, the former state geologist of Pennsylvania and admirable stratigraphical geologist, correlated the corresponding rocks of Pennsylvania with the Salina. In Bedford county, Pennsylvania, which lies immediately north of the Cumberland region, Professor Lesley gave the upper and middle divisions of the Salina as 628 feet in thickness to which is to be added a portion of the 472 feet composing the lower Salina which included the Niagara beds at its bottom.[1] Mr. Schuchert also fully concurs in correlating these Maryland beds with the Salina.

---

[1] Letter of June 26, 1901.

[2] Mr. Schuchert has recently studied this formation in the Cumberland region and he writes me as follows: "I am inclined to cut out of the Salina the lower 23′ 6″ as given on p. 93 of O'Harra's report (Maryland Geological Survey, Allegany county). This thickness I now refer to the rest of the Niagara. I also extend the Salina a little higher, making the total thickness 704′." (Letter of June 26, 1901.)

[3] Am. Jour. Sci., 4th ser., Vol. XI, p. 240, 1901.

DEVONIAN STRATA [2]

Helderberg limestone.—The largest area covered by this formation is in the central part of the county which it enters to the north of Flintstone and then runs in a zigzag manner back and forth until it leaves the county on the western side of Evitt's Mountain. Another area follows Shriver Ridge and passes through western Cumberland across the county. A third area enters in the eastern part of Wills Creek valley and runs across the county, keeping west of Wills Mountain, to Potomac Station; and, finally, to the southwest is the Fort Hill area, beween Rawlings and Dawson. The best localities for studying this formation are the Devil's Backbone, northwest of Cumberland; the cliff on the West Virginia side at Cedar Cliff and the Baltimore and Ohio Railroad cut near Potomac Station. The lower 400 feet of the formation is composed of fairly thin-bedded bluish-gray limestones, separate pieces of which have a metallic ring when sharply hit. The more shaly layers contain fossils among which are *Tentaculites gyracanthus* and *Spirifer vanuxemi*, characteristic species of the Tentaculite limestone in New York with which this zone is correlated.

Messrs. Clarke and Schuchert in their revised classification revived Vanuxem's geographical name of Manlius limestone for the paleontological one of Tentaculite limestone.[3] The Maryland zone was put in the Helderbergian instead of the Cayugan period because, as clearly stated by Dr. O'Harra, "the lithological break between it and the Salina is very marked and can be followed in the field . . . . while there is no lithological break between the Tentaculite and Lower Pentamerus subformations, and the division for mapping purposes cannot be made here."[4]

---

[1] Summary Description Geol. Pennsylvania, Vol. II, p. 839, 1892.

[2] The Geological Survey of Maryland has followed Dr. Clarke and Mr. Schuchert in referring the Helderbergian period to the Devonian system.

[3] Science, N. S., Vol. X, pp. 876, 877, 1899.

[4] Allegany county, p. 96.

Higher in the formation are massive darker blue limestones, about 240 feet in thickness according to Schuchert or from 50 to 150 feet as given in Rowe's report, some of the layers of which contain numerous specimens of *Pentamerus* (*Sieberella*) *galeatus*. This zone probably represents the Lower Pentamerus limestone of New York, of which the above fossil is a characteristic species.

In place of the paleontological name Lower Pentamerus limestone, Messrs. Clarke and Schuchert proposed Coeymans limestone.[1]

In the upper fifty feet or more of the limestones are frequent specimens of *Spirifer macropleurus* characteristic of the Delthyris shaly limestone of New York, with which this zone is correlated. In New York this division of the Helderberg consists of calcareous shales and shaly limestones with some beds a foot or more in thickness, but in Maryland it is composed mainly of fairly massive limestone. With the exception of the Lower Pentamerus, all the Helderberg limestones are more massive in Maryland than in New York. In place of the term Catskill or Delthyris shaly limestone Messrs. Clarke and Schuchert proposed the geographic name of New Scotland beds.[2]

The Becraft limestone, which caps the Helderberg limestone of New York, is apparently not represented in Allegany county, although some eighty-five feet of it occurs farther east in Washington county, Md.

The thickness of the foundation varies from 750 to 900 feet, and fossils are common in some of the layers. The limestones are valuable for quicklime, ballast, road-metal, and building purposes. The formation is named from the lower limestones of the Helderberg Mountains in eastern New York, and is the equivalent of No. VI of the Pennsylvania survey, and the upper part of the Lewistown formation of the Piedmont folio.

Oriskany sandstone.—The easternmost area of Oriskany sandstone is that of Stratford Ridge, to the northeast of Oldtown; then follows that of the central part of the county bordering the zigzag Helderberg area; then, in order named, that crossing the county along the eastern side of Shriver Ridge; the narrow band extending across the county to the west of the Helderberg area west of Wills Mountain; to the southwest the band on the western side of Fort Hill, and, lastly, the area extending from the Twenty-first Bridge to Monster Rock at Keyser.

---

[1] Science, N. S., Vol. X, pp. 876, 877.

[2] *Ibid.*, pp. 876, 877.

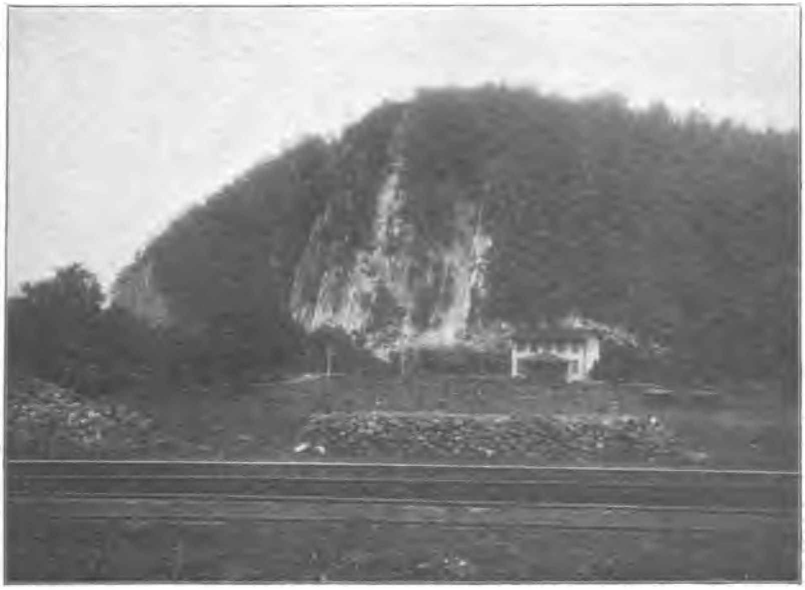


FIG. 1.—Devil's Backbone, near Cumberland, showing Helderberg limestone in the steeper part and Oriskany sandstone in the farther railroad cut.

The lower part of the formation is mainly a bluish-black cherty limestone, 75 to 100 feet in thickness, the chert in nodules and layers, with some dark gray arenaceous shales; and the remainder of the formation is mostly a sandstone, frequently calcareous, and varying in color from gray to white, about 250 feet in thickness. Toward the top there are a few bands varying from grit to conglomerate. The sandstone, on account of its calcareous cement, weathers readily to a friable brownish or buff, porous rock, which, when protected from erosion eventually forms beds of sand. Its thickness varies from 325 to 350 feet. It furnishes railroad ballast and good glass sand. Fossils occur abundantly in zones varying in thickness from an inch to several feet. The most perfect specimens may be obtained from the beds of sand from the disintegrated rock, and frequently from pockets of sand in the partly weathered rock. *Spirifer arenosus* and other common species of the formation in New York are abundant, together with species which are restricted to its southern distribution. There are numerous springs along the contact of the Helderberg and the Oriskany sandstone. The formation is named from outcrops near Oriskany Falls, in central New York; is known as No. VII in Pennsylvania; and is the Monterey sandstone of the Piedmont folio.

Romney formation.—This formation enters the county on the eastern side of Iron Ore Ridge, northeast of Flintstone, crosses it and covers a large area to the east, north, and west of Oldtown, then alternates with the Oriskany areas in the southern central part of the county, and finally crosses in a V-shaped area—the eastern arm west of Nicholas Mountain, the point along Evitt's Creek, and the western arm passing through the eastern part of Cumberland. The western area enters the county at Ellerslie, crosses it to the Potomac River, and then extends southwest to the bend in the river at Keyser, W. Va.

The transition from the Oriskany sandsone to the black shale of the Romney is very abrupt, as may be seen at various exposures of the contact, especially east of the church on the Williams Road, two and one half miles southeast of Cumberland, and at Monster Rock on the W. Va. Central Railroad, near Keyser, W. Va. The lower part of the formation is composed of thin black shales, weathering to a rusty brown, in which are some bands of bluish-gray limestone about 150 feet above the base. This portion of the formation is well shown in the two railroad cuts just north of the Twenty-first Bridge on the Baltimore and Ohio Railroad. The black shales contain specimens of *Liorhynchus limitaris* and other small fossils, and in lithological characters agree with Marcellus shale of New York or No.

VIII*b* of Pennsylvania, which they represent. The higher rocks are drab and bluish argillaceous to arenaceous shales and thin sandstones, which usually weather to an olive or yellowish-gray tint. At certain localities they are very fossiliferous, containing numerous specimens of *Spirifer granulosus*, *S. mucronatus*, *Athyris spiriferoides*, *Tropidoleptus carinatus*, *Chonetes coronata*, *Phacops rana* and other characteristic species of the Hamilton formation of New York, the fauna amounting to about 150 species. The formation, which varies in thickness from 1600 to 1650 feet, is named from the exposures near Romney, in northeastern West Virginia, and represents the Marcellus shale and Hamilton beds of New York, and No. VIII*b* and *c* of Pennsylvania.

In 1842 Emmons proposed the name Erie group for all the New York rocks between the base of the Marcellus shales and the top of the Chemung.[1] Mr. Darton, in 1892, proposed and defined the Romney shales, named from exposures in the vicinity of Romney, Hampshire county, in northeastern West Virginia,[2] which are now known to be equivalent to the Marcellus shales and Hamilton beds of New York. Messrs. Clarke and Schuchert, in 1899, used the term Erian in their revised classification of the New York series for the group composed of the Marcellus shales and Hamilton beds, and stated that it represented the "Erie Division" revived with a restricted meaning.[3]

It appears that the Romney formation is equivalent to the Erian group of New York; but the writer is undecided as to which name the laws of nomenclature entitle to recognition in Maryland.

Jennings formation.—The eastern area crosses the eastern part of the county from the northeast to the southwest; the second area lies to the west of Green Ridge, and in its northern half covers a large district to the north and east of the Romney formation; the third covers the lower part of Evitt's Creek valley between the two arms of the V-shaped Romney area, and the fourth one is the broad band covering the lower part of the eastern face of Alleghany Front and extending from the Pennsylvania line southwesterly to the Potomac River above Keyser, W. Va. The lower part of the formation composed of thin, black, argillaceous shales in which a few species, such as *Buchiola speciosa*, *Lunulicardium fragile*, and *Styliolina fissurella* are common, immediately succeeds beds containing characteristic Hamilton fossils, and is well shown on Flintstone Creek, a few rods above its mouth, opposite the old Flintstone tannery; by the side of the National Road three miles northeast of Cumberland to the west of Evitt's Creek at Folks Mill, and on the Williams road east of Cumberland. This subformation corresponds in lithologic character and stratigraphic position to the Genesee shale of New York and No. VIII*e* of Pennsylvania.

---

[1] Geology, New York, Pt. II, pp. 100, 429.

[2] Am. Geologist, Vol. X, pp. 17, 18.

[3] Science, N. S., Vol. X, pp. 876, 877.

Following this are olive to bluish fine argillaceous shales alternating with thin bedded sandstones. A few fossils occur in the more bluish layers. This division of the Jennings corresponds to the Portage formation of New York, or that facies named the Naples beds by Dr. Clarke, and No. VIII*f* of Pennsylvania. Dr. J. M. Clarke, who has described the Jennings fauna for the Maryland Geological Survey, writes me that the fauna of these two lower divisions of the Jennings formation "is very distinctly that of the Naples subprovince;" and he states that the lower division is considered "as an integral part of the Naples beds, bearing the Naples fauna."[1]

Succeeding the Portage are greenish arenaceous shales weathering to a buff color alternating with thin micaceous sandstones. Occasional layers are fossiliferous and the characteristic Chemung species, *Spirifer disjunctus*, is not uncommon. The lithological appearance of this part of the formation is quite similar to that of a considerable part of the Chemung in southwestern New York. Higher the sandstones predominate, and these vary in color from yellowish-gray through brownish-gray to dark red, and vary in texture from sandstone and grits to a white pebble conglomerate. Some of these sandstones are quite massive, and in Jennings Run about one and one half miles above Corrigansville, a zone of grit and sandstone is thirty-five feet thick. The red rocks increase above this horizon, but Chemung fossils including *Spirifer disjunctus* extend some 650 feet higher, and the line between the Jennings and Hampshire formations has been drawn at the top of this fauna. The formation is between 3800 and 4000 feet in thickness. The upper part of the Jennings may be correlated with the Chemung of New York or No. VIII*g* of Pennsylvania.

---

[1] Letter of June 19, 1901.

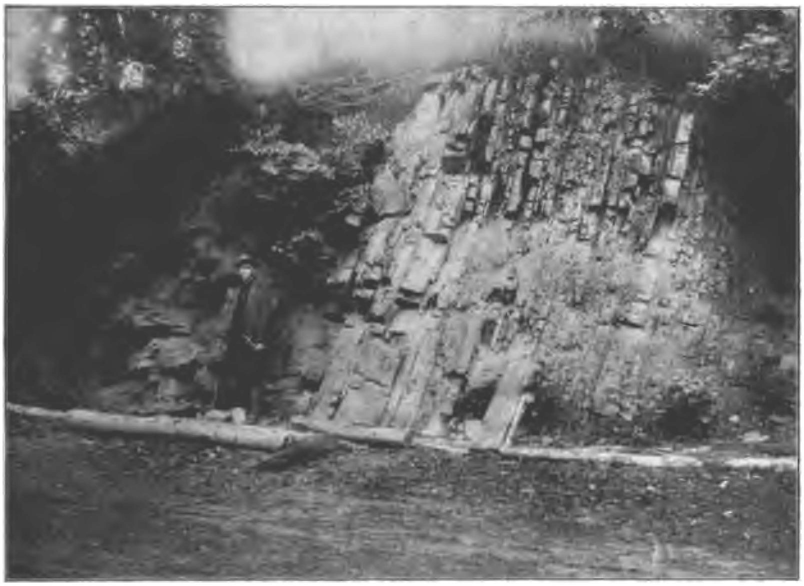


FIG. 2.—Heavy sandstone and conglomerate beds in the upper part of the Jennings formation, as shown by the roadside above Corriganville.

Hampshire formation.—This formation crosses the extreme eastern part of the county from the northeast to the southwest; the next area, which is the largest, flanks each side of Town Hill and crosses the county in the same general direction; while the third extends along the middle part of the eastern face of Alleghany Front. The rocks consist mainly of an alternation of red, flaggy, and massive sandstones and arenaceous or argillaceous shales which both laterally and vertically merge gradually into each other and in the upper part of the formation shales, some of which are gray, and some brown in color, predominate. Some of the sandstones are crossbedded, and in the lower part of the formation, massive. The thickness varies from 1900 to 2000 feet. Fossils occur very infrequently. The formation is named from Hampshire county in northeastern West Virginia, a considerable area of which is underlain by it, and it represents at least part of the Catskill formation of New York, or No. IX of Pennsylvania.

CARBONIFEROUS STRATA

Pocono sandstone—The most eastern area of this formation, which forms the upper part of Town Hill, is mainly a massive conglomerate, while in the western area, extending across the county from Pennsylvania to West Virginia along the eastern face of Alleghany Front, the lower part of the formation is a coarse-grained, grayish-green, micaceous sandstone. Near the middle are shales containing fragments of plants, and the upper part is a grayish-green or reddish-green, micaceous, flaggy sandstone with some interbedded shales of various colors. Some of the layers are cross-bedded and others are conglomeratic. The thickness varies from 400 to 450 feet, and fragments of plants are the only fossils noted with the exception of a few shells apparently from this formation which were found nine miles northeast of Oakland, Garrett county. The formation is named from Pocono plateau in northeastern Pennsylvania, and is No. X of the Pennsylvania reports.

Greenbrier limestone.—This formation crosses the county as a narrow band along the eastern face of the Alleghany Front from Pennsylvania to West Virginia. The best exposures are in Jennings Run above the railroad water-tank; and on the north bank of the Potomac River below the mouth of Stony Run, as well as in the lower part of the run, two miles below Westernport. The lower part of the formation is composed largely of bluish-gray, arenaceous limestone, the middle of red and olive shales and the upper part of massive bluish-gray limestones and calcareous shales. The limestone is valuable for road-metal and in Garrett county is quarried and burned to a considerable extent for quicklime which is used as a fertilizer. The thickness varies from 200 to 250 feet and the upper part is quite fossiliferous. The formation is named from Greenbrier county in southeastern West Virginia where it reaches a thickness of 1000 feet or more.

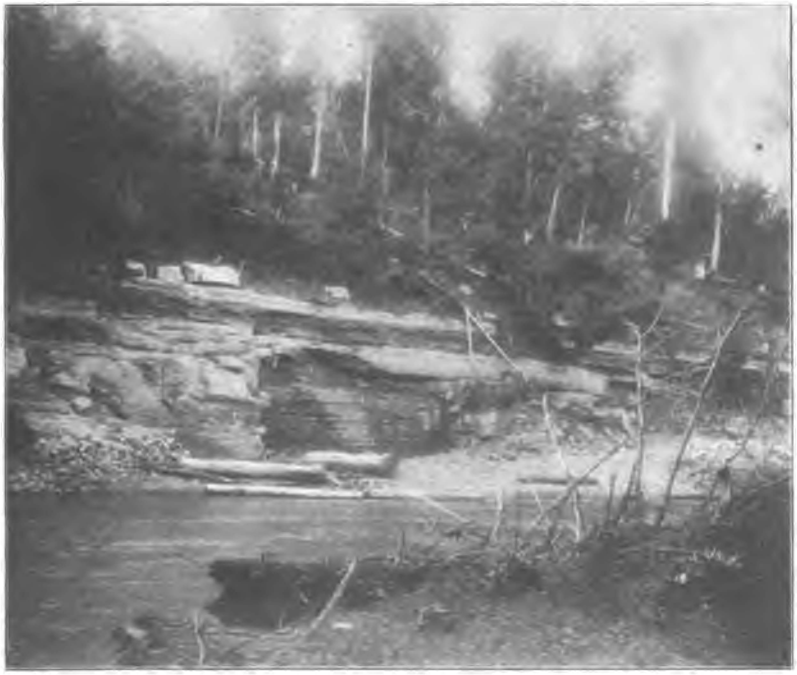


FIG. 3.—Greenbrier limestone on western bank of Youghiogheny River, southwest of Oakland, Md.

Mauch Chunk formation.—This, like the preceding formation, crosses the county along the eastern face of Alleghany Front but the band is broader, covering the upper part of the mountain slope. The rocks are mainly red arenaceous and argillaceous shales and sandstones, but a little above the middle of the formation is about 100 feet of reddish thin-bedded standstones. At the top of the formation, as shown in the Cumberland and Pennsylvania R. R. cut east of Barrelville, is a greenish zone five feet thick composed partly of sandstone and partly of a calcareous breccia containing clay pebbles. The thickness of the formation is 650 feet. In the lower part of the shales and along the Greenbrier–Mauch Chunk contact are numerous excellent springs. The formation is named from Mauch Chunk in eastern Pennsylvania and is the Canaan formation of the Piedmont folio. The Greenbrier limestone and Mauch Chunk shales taken together are known as No. XI of the Pennsylvania reports.

Pottsville formation.—The preceding three formations are usually grouped together as the sub-Carboniferous or Lower Carboniferous, and the Pottsville is classed as the oldest of the Carboniferous proper or Upper Carboniferous formations. It crosses the county from Pennsylvania to the Potomac, in general forming the crest line of Alleghany Front although in the northern part it is lower, and extends up the Potomac valley to above Westernport. At numerous places near the crest line of Alleghany Front it forms conspicuous cliffs. It also occurs at the northwestern corner of the county. The formation is composed of massive light gray sandstones with some conglomerate strata and thin-bedded gray sandstones and shales. Some of the shales are black and there are several thin beds of coal. The most important are first, the Bloomington, which is exposed along the Baltimore and Ohio Railroad west of Piedmont, W. Va., commonly known as the Railroad seam, varying in thickness from less than two to more than three feet and occurring about 150 feet below the top of the formation. The second is the Westernport seam about two feet thick which occurs below the Homewood sandstone near the top of the formation. Some of the sandstones are suitable for building stone. The thickness is estimated as between 450 and 500 feet and there are fragments of fossil plants. The formation is named from the exposures of massive conglomerate in the vicinity of Pottsville in eastern Pennsylvania. It is the Blackwater formation of the Piedmont folio and No. XII of the Pennsylvania reports.

formation. From 225 to 230 feet above the Thomas coal and base of the formation and about 400 feet below the Elkgarden coal is a coal seam with a general thickness of four feet, but varying from three to nearly five feet, named the Barton (Four-foot) coal, and worked to a considerable extent in the vicinity of that town. A thin seam nearly one foot thick in outcrop occurs about 440 feet above the Thomas coal or 220 feet below the Elkgarden, while approximately 500 feet above the Thomas coal and 150 feet below the Elkgarden coal is a zone composed of alternating shales and impure coal, varying in thickness from seven to ten feet, known locally as the "Dirty Nine-foot" and called the "Franklin" coal. In the Lonaconing section, thirteen feet below the base of the Franklin coal are nearly three feet of coal and black, thin shale. There are also two or three impure limestone strata and some irregular beds of iron ore. The formation is clearly defined by the top of the Thomas coal at the base and the base of the Elkgarden (Pittsburg) coal at the top, the thickness varying from 600 to nearly 640 feet. A few invertebrate fossils have been found, principally on the bank of George's Creek at Barton, and fossil plants in the black shales.

The Conemaugh formation was named from the Conemaugh River in western Pennsylvania, is frequently called the Lower Barren-measures, is No. XIV of the Pennsylvania reports, is the upper part of the Bayard and Fairfax formation of the Piedmont folio, and the Elk River series of West Virginia.

Monongahela formation.—This formation, south of an east and west line passing through Little Alleghany, covers the larger part of George's Creek valley as far south as Ocean and most of the area west to the county line. To the north of Little Alleghany, two high hills are capped by it. From Ocean to Lonaconing the upper part of the steep hills bounding the George's Creek valley are in the Monongahela, which also caps most of the highest hills as far south as Hampshire to the northeast of Westernport. The rocks consist largely of light gray to black shales with some grayish sandstones which form occasional massive strata. There are also several dark colored limestones, (Clarion) coal with a thickness of two feet which was reported by the miners to reach 4½ feet. At Westernport nearly 100 feet above the base is an impure coal, called the "Split six-foot" by the miners, showing a thickness of 4 feet, and 130 feet above the base is the most valuable coal seam of this formation, the "Davis" (Lower Kittanning), commonly known as the "Six-foot," with a thickness of about 5 feet in the lower George's Creek valley. Nearly 170 feet above the Davis seam is the "Thomas" (Upper Freeport) coal, which forms the top of the formation, and from its general thickness in the George's Creek valley is known as the "Three-foot" seam. Fossil shells have been found in the black or bluish shales at a few localities. The thickness of the formation is about 300 feet. It is named from the exposures on the Allegheny River in western Pennsylvania, is very generally called the Lower Productive-measures, is No. XIII of the Pennsylvania survey and includes the Savage formation and lower part of the Bayard of the Piedmont folio.

Conemaugh formation.—The area south of the Pennsylvania line to a parallel line passing through Little Alleghany and to the west of the foot of the western slope of Little Alleghany and Piney mountains is largely covered by this formation. Then it extends parallel to Dan's Mountain, to the southwestern part of the county and covers a large portion of the steep slopes of the hills bordering the lower George's Creek valley, continuing up the valley to Ocean. It also appears in the upper part of a number of the small valleys along the western border of the county. The lower part of the formation, representing the Mahoning sandstone, is frequently a massive gray sandstone with bands of yellowish shales reaching a thickness of about 100 feet. In the upper part of this sandstone, about eighty-five feet above the Thomas coal, is a coal seam about two feet in thickness underlain by a stratum of fire clay. The succeeding rocks are grayish to brownish sandstones and yellowish to gray and black arenaceous and arigillaceous shales with beds of coal and fire clay. In some of the localities there are quite massive gray to brownish-gray sandstones near the middle and top of the formation. From 225 to 230 feet above the Thomas coal and base of the formation and about 400 feet below the Elkgarden coal is a coal seam with a general thickness of four feet, but varying from three to nearly five feet, named the Barton (Four-foot) coal, and worked to a considerable extent in the vicinity of that town. A thin seam nearly one foot thick in outcrop occurs about 440 feet above the Thomas coal or 220 feet below the Elkgarden, while approximately 500 feet above the Thomas coal and 150 feet below the Elkgarden coal is a zone composed of alternating shales and impure coal, varying in thickness from seven to ten feet, known locally as the "Dirty Nine-foot" and called the "Franklin" coal. In the Lonaconing section, thirteen feet below the base of the Franklin coal are nearly three feet of coal and black, thin shale. There are also two or three impure limestone strata and some irregular beds of iron ore. The formation is clearly defined by the top of the Thomas coal at the base and the base of the Elkgarden (Pittsburg) coal at the top, the thickness varying from 600 to nearly 640 feet. A few invertebrate fossils have been found, principally on the bank of George's Creek at Barton, and fossil plants in the black shales.

The Conemaugh formation was named from the Conemaugh River in western Pennsylvania, is frequently called the Lower Barren-measures, is No. XIV of the Pennsylvania reports, is the upper part of the Bayard and Fairfax formation of the Piedmont folio, and the Elk River series of West Virginia.

Monongahela formation.—This formation, south of an east and west line passing through Little Alleghany, covers the larger part of George's Creek valley as far south as Ocean and most of the area west to the county line. To the north of Little Alleghany, two high hills are capped by it. From Ocean to Lonaconing the upper part of the steep hills bounding the George's Creek valley are in the Monongahela, which also caps most of the highest hills as far south as Hampshire to the northeast of Westernport. The rocks consist largely of light gray to black shales with some grayish sandstones which form occasional massive strata. There are also several dark colored limestones, bands of iron ore, and beds of coal. The Elkgarden (Pittsburg) coal, the noted seam of western Maryland, and known locally as the "Big Vein" or "Fourteen-foot" seam, occurs at the base of this formation. The main mass of coal varies in thickness from ten to nearly fourteen feet, above which are frequently from three to nine feet of alternating coal and black shale which, in the southern part of the George's Creek field, is capped by twenty-five feet of thin black shales in which coal occasionally occurs.

A seam of coal two and one half feet in thickness is reported in the Consolidation Coal Company's new shaft 92 feet above the base of the Elkgarden coal. From 120 to 140 feet above the top of the Elkgarden is the Tyson (Sewickley) coal varying in thickness from three to seven feet. Finally, at the top of the formation about 255 feet above the base of the Elkgarden coal is the Koontz (Waynesburg) coal two feet thick and reported to reach a thickness of four and one half feet. The top of this coal determines the upper limit of the Monongahela formation which has a thickness of a little more than 250 feet. Fossils are rare.

The Monongahela formation was named from the exposures along the Monongahela River in southwestern Pennsylvania, is popularly known as the Upper Productive-measures, is No. XV of the Pennsylvania reports and the Elkgarden formation of the Piedmont folio.

PERMIAN STRATA (?)

Dunkard formation.—The largest area of this formation partly underlies the city of Frostburg and covers a considerable tract to the east and southeast of the city. It covers the high part of several hills to the south of Frostburg, extending as far south as Detmold Hill on the western side of George's Creek and the hill south of Pekin on the eastern side. The rocks consist largely of argillaceous shales, which when weathered are reddish-green, with some beds of sandstone, limestone, and coal. A stratum of coal and black shale four feet thick occurs 120 feet above the base of the formation and a drab limestone, five feet thick, weathering buff occurs about 295 feet above it. This limestone, some of the layers of which contain plenty of specimens of Ostracods (*Primatia frostburgensis* Jones) and a few other species, has been quarried to some extent toward the top of Vale's Hill, east of the Consolidation Coal Company's pumping station, and it is succeeded by thin black shales. The top of the hill is ninety feet higher and on its slope forty feet above the limestone ledge are loose pieces of bluish thin-bedded limestone containing small Ostracod and Gastropod shells. Near the top are loose blocks of coarse-grained sandstone which probably caps the hill. This hill shows about 390 feet of the Dunkard formation, which is probably its greatest thickness in the county. In addition to the fossils noted in the limestones, ferns were found in the shales overlying the Koontz coal.

The formation is named from the exposures along Dunkard Creek, near the West Virginia-Pennsylvania line, is frequently called the Upper Barren-measures, and is No. XVI of the Pennsylvania report.

CHARLES S. PROSSER.

COLUMBUS, O.,
July 1901.

THE DEPOSITION OF COPPER BY SOLUTIONS OF FERROUS SALTS

INTRODUCTORY

THE genesis of the great deposits of native copper is a subject which has invited considerable speculation. From its occurrence in the cupriferous conglomerates and sandstones as a cement, or replacer, of the constituent grains, the copper is plainly of secondary origin. Its position here indicates that it resulted as a deposition from aqueous solution.[1] The metal, doubtless, first dissolved as sulphate, an oxidation-product of an original sulphide. Under the influence of solutions of calcium bicarbonate, or alkaline silicates, the sulphate was speedily converted into the carbonate, or silicate.[2] From solutions of one, or both, of these latter salts were probably derived the several classes of copper deposits.

In its paragenetic relations the position of the metallic copper indicates, as Pumpelly shows, that it was deposited after the formation of the non-alkaline silicates and before that of the alkaline silicates. As is further pointed out by the same writer, there is an intimate connection between the native copper and such iron-bearing minerals as delessite, epidote, and the green earth silicates. So constant is their common occurrence that he is led irresistibly to the conclusion that there is a close genetic relation between the reduced copper and the ferric oxide contained in the associated minerals; that, indeed, the reduction of the copper oxide to metallic copper was produced by the oxidation of ferrous derivatives. Later Irving, in support of the same view, called attention to the fact that many particles of copper enclosed a central core of magnetite.[3]

---

[1] R. D. IRVING: Mon. U. S. Geol. Surv., No. 5 (1883), p. 420.

[2] RAPHAEL PUMPELLY: Am. Jour. Sci., Vol. II (1871), p. 353.

[3] Mon. U. S. Geol. Surv., loc. cit.

A number of attempts has been made to discover the conditions under which copper may be deposited by solutions of ferrous salts. As early as 1861, Knop succeeded in forming cuprous hydroxide by treating a mixture of cupric and ferrous sulphates with alkaline carbonate.[1] In one instance he speaks of obtaining traces of copper. In 1864, Wibel repeated Knop's experiments,[2] but was unable to verify the latter's statement regarding the reduction to metallic copper. When, however, a mixture of ferrous and cupric hydroxides, formed by adding potassium hydroxide to a solution of the sulphates, was heated to 210° C., traces of copper were obtained. Solutions of the sulphates and coarsely powdered Wollastonite, subjected to the same treatment, yielded a like result. The separation of metal, however, was slight and the part played by the ferrous hydroxide in the reduction was at the time somewhat questioned. In 1867, Braun observed the partial deposition of copper from a mixture of ferrous and cupric salts when these were dissolved in large excess of ammonium carbonate.[3] The same year Weith secured a ready reduction in the presence of tartaric acid.[4] He failed to note, however, that under the same conditions, the organic acid itself will slowly reduce the copper salt. A mixture of calcium hydroxide with a solution of ferrous and cupric sulphates, was allowed to stand for several weeks. The precipitate thus obtained, when treated with acetic acid, left a residue of cuprous oxide and copper.

Strangely enough Weith overlooked the fact that cuprous oxide with acetic acid yields cupric acetate and metallic copper. In 1869, Hunt[5] stated that he had obtained metallic copper by the action of cupric chloride on freshly precipitated ferrous hydroxide, or carbonate. Nothing is given, however, to indicate that the metal was actually detected by isolating it from co-precipitated ferric hydroxide.

---

[1] A. Knop: N. Jahrb. f. Min. (1861), S. 513.

[2] Ferd. Wibel: "Das Gediegen-Kupfer und das Rothkupfererz" (1864), S. 14.

[3] E. Braun: Zeit. für Chem. (1867), 569.

[4] W. Weith: Zeit. für Chem. (1867), 623.

[5] Sterry Hunt: Comp. r. (1869), 1357.

THEORETICAL

It can be shown that the deposition of copper by solutions of ferrous salts is a reversible reaction governed by the ordinary laws of chemical equilibrium. It is to Arrhenius largely that we owe the view that certain substances in solution are more, or less, dissociated into electrically charged parts, or ions. This theory has proved of the highest value in affording an insight into the principles of chemical reactions. Different substances differ much in their tendency to pass into the ionic form and this tendency is greatly influenced by external conditions, particularly by the nature of the solvent.

The chief source of ions is the dissociation of electrically neutral molecules, such as occurs in the aqueous solutions of salts, acids, and bases. They may further be formed from electrically neutral substances which enter the ionic condition by partially, or wholly, appropriating the electric charge of ions already present.[1] As an example of this mode of formation may be mentioned the reduction of ferric salts by the action of metallic iron. $2FeCl_3 + Fe = 3FeCl_2$. The solution of metallic copper in ferric chloride is an action of the same nature. $Cu + 2FeCl_3 = CuCl_2 + 2FeCl_2$.

As is seen the deposition of copper by a ferrous salt would be the reverse of this last reaction.

The conditions under which such reduction should occur may be readily determined. In a system which contains a solution of iron and cupric salts in contact with metallic copper and in which the several constituents have attained a constant value, a condition of equilibrium subsists on the one hand between ferric, cuprous, ferrous, and cupric ions ($Fe^{'''} + Cu^{'} \rightleftarrows Fe^{''} + Cu^{''}$), and on the other hand between ferric, ferrous, and cuprous ions and the active mass of the metallic copper ($Cu + Fe^{'''} \rightleftarrows Fe^{''} + Cu^{'}$). If a, b, c, d, respectively, represent the active masses of the ions in the first instance, an equation of equilibrium may be thus formulated, $\frac{ab}{cd} = K$.[2] The active mass of the copper is of constant value, hence in the second instance, retaining the same letters, we have the expression, $\frac{a}{bc}=K'$. The precipitation of copper would then be favored by increasing the concentration of ferrous, cuprous, and cupric ions and by decreasing that of the ferric ions. The deposition of the metal, consequently, should depend on the relative active masses of the ions present. This assumption is fully sustained by the experimental evidence which follows:

---

[1] F. W. Küster: Zeit. f. Elec. Chem., Vol. IV, p. 105.

[2] W. Nernst: Theoretical Chemistry, p. 358.

The precipitation of metallic copper by solutions of ferrous salts is a reversible action, whose direction in any case is determined by the relative concentration of the ferrous, ferric, and copper (cuprous and cupric) ions.

EXPERIMENTAL [1]

(*a*) In a solution containing an appreciable quantity of ferric ions, or in which these would be formed in the course of the reaction, metallic copper will not be deposited.

This is shown in the inability of ferrous chloride, or sulphate, to reduce corresponding copper salts, even though the mixed solutions stand for an indefinite period. This inaction is, indeed, to be expected when we consider that solutions of soluble ferric salts, as the sulphate and chloride, easily dissolve metallic copper with formation of a cupric salt.

From this it is readily understood why Wibel [2] obtained no reduction of the copper salt on heating together to 210° C. a solution of the mixed sulphates.

(*b*) In a solution containing few ferric ions and in which the reaction does not result in their appreciable increase, a sufficient concentration of ferrous and copper ions will result in the deposition of metallic copper.

The tendency of ferrous to reduce copper salts is shown in the precipitation of cuprous sulphocyanate by the action of the ammonium salt on a solution of ferrous and cupric chlorides. The same tendency appears in the formation of cuprous chloride, as noted by Hunt, on heating cupric oxide with a solution of ferrous chloride.[1] From an emulsion of ferrous and cupric hydroxides, after long standing, may be separated crystals of cuprous oxide. That further reduction is largely determined by the concentration of the cupric and ferrous ions, appears probable from the action of ammonium carbonate on a solution of ferrous and cupric chlorides.[2] The precipitate first formed on adding the carbonate to the mixed chlorides, dissolves in an excess of the precipitant to a yellow liquid, from which, on standing twenty-four hours, there is deposited, on the walls of the vessel, a slight but brilliant mirror of metallic copper.

---

[1] All the reactions given in the following paragraph have been experimentally determined by its author except as indicated by references.—Ed. JOUR. GEOL.

[2] "Das Gediegen-Kupfer und das Rothkupfrerz," S. 20.

The influence of the concentration of the ions on the reduction of copper is clearly shown in the behavior of the mixed carbonates under varying conditions.

When one adds a solution of cupric and ferrous chlorides (1 mol. $CuCl_2$: 2 mol. $FeCl_2$) to a considerable excess of sodium carbonate, there is obtained a greenish precipitate of the carbonates which undergoes but slight change on standing. Such a solution, indeed, would naturally little favor the separation of metallic copper since the highly ionized alkaline carbonate would greatly decrease the active masses of the ferrous and cupric ions.

If the alkaline carbonate employed be only slightly in excess of that required to precipitate the copper and iron salts, the concentration of the carbonic acid ions will be greatly diminished. Under these more favorable conditions reduction slowly takes place with loss of carbon dioxide. The carbonates gradually change in color to a brick-red precipitate containing metallic copper and basic ferric carbonate.

As is well known the acid ferrous and cupric carbonates are more soluble than the corresponding normal or basic salts of these metals. The influence of this greater solubility is shown in the precipitation of small amounts of copper even in the presence of large excess of acid alkaline carbonates. If one adds the metallic chlorides to a saturated solution of acid potassium carbonate and allows the mixture to stand for twenty-four hours there is deposited on the walls of the vessel a slight film of metallic copper mixed with basic ferric carbonate.

---

[1] STERRY HUNT: Comp. r., loc. cit.

[2] E. BRAUN: Zeit. für Chem., loc. cit.

The solubility of the acid carbonates of iron and copper is largely increased under pressure.[1] The greater concentration of the metallic ions thus obtained produces a ready reduction of copper even in the presence of concentrated solutions of the acid alkaline carbonates.

In a thick-walled flask holding a saturated solution of potassium bicarbonate is placed a tube containing a solution of ferrous and cupric chlorides. The flask is then filled with carbon dioxide, tightly sealed, and the contents of the tube mixed with the alkaline bicarbonate. The precipitate formed gradually loses carbonic acid, finally assuming the brick-red color already noted. The supernatant ruddy liquid owes its color to the presence of some basic ferric carbonate which, when the solution is warmed, deposits as ferric hydroxide. The precipitate contains finely divided copper which cannot readily be freed from the intimately associated ferric iron by treatment with hydrochloric acid because of the solvent action of ferric chloride, but on digesting the original mixture a short time a coagulum may usually be formed from which, by repeated agitation with water, the heavier metal is separated. The copper thus obtained is of characteristic appearance; is insoluble in hydrochloric acid, soluble in nitric, the solution showing the presence of copper and absence of iron.

The reduction of copper from the cuprous condition may be effected in the same manner as from the cupric. This is readily shown by substituting for the cupric salt in the above reaction cuprous chloride dissolved in a solution of chloride of sodium. From one gram of cuprous chloride more than half the metal may be easily isolated as pure copper free from ferric iron.

From these results it is quite evident that the conditions under which the oxidation of ferrous salts may result in the deposition of copper are those which obtain in the circulation of underground waters. The theory of Pumpelly and others based on paragenetic relations is thus fully sustained by chemical evidence.

---

[1] R. WAGNER: Zeit. f. analyt. Chem. Vol. VI, p. 167.

H. C. BIDDLE.

UNIVERSITY OF CHICAGO,
June 1901.

EVIDENCE OF A LOCAL SUBSIDENCE IN THE INTERIOR

In the spring of 1883, I made a survey to build a levee along the Wabash River on the west side of Parke county, Indiana, for a length of twelve miles. I took the levels with great care, and checked on the river water every half mile to guard against errors. The great flood of the preceding winter had left its high water mark very plain on the trees in the bottoms, and I checked on them also. I cut some sixty bench marks on the trees in running the levels, some of which are still intact. The lower end of the levee was built square across the narrow bottom to the bluff and crossed a bayou through which the flood water ran off of the bottoms into the river. We built an automatic floodgate across this bayou so as to shut out river, but let out inside water from breaks above. The gates were hung to heavy brick walls built on timber foundations three feet thick, and deeply bedded below the bottom of the bayou. A bench mark was cut on a bur oak tree near the walls, and the level of the walls was taken when built. I had charge of the maintenance and repair of this levee four years from its building, and had frequent occasion to run the level over the top to restore breaks, for it was built only twenty-one feet above low water, whereas the great floods rise twenty-eight feet. I set the grade stakes for the contractors to work to, and in doing so ran the level over the ground again. I speak of all this to show that my leveling was correct, as so many levelings would detect any error, and none were found to exceed a half inch. I can say positively that the levels were correct in 1883.

This spring (1901) the levee was to be raised three feet, making it twenty-four feet above low water, under a new law of the state, but including only the lower seven miles. I leveled the work again, and found bench marks again intact except the lower (south) mile and a quarter, which showed a decline southward amounting to ten inches at the lower (south) end, as shown by the mark on the bur oak and top of the gate walls. I went back to the C. & E. I. railroad bridge at Clinton, two and a half miles above the south end, and started my level from a mark known to be in tally with the level of 1883, and ran carefully over the work again, and it varied from the one made just before only a quarter of an inch. And the bench mark on the bur oak and the top of the gate walls had gone down ten inches ($\frac{83}{100}$ of a foot). I was right in 1883 and I am right now. What caused this sink, or subsidence? I can think of nothing so likely to cause it as the Charleston earthquake. The wave of that earthquake somewhere south of us changed from westward and went northward along the Wabash.

JOHN T. CAMPBELL.

ROCKVILLE, INDIANA,
July 20, 1901.

EDITORIAL

WITH the death of Dr. Joseph Le Conte there has passed away perhaps the last distinguished American representative of the general geologist as typified during the past century. This passing type of the general geologist was a distinctive outgrowth and representative of a transitional stage of intellectual procedure—a passage from the former mode in which the generalizing and philosophical factors held precedence and the toilsome modes of scientific verification followed as their servitors, to the present or at least the coming method in which scientific determinations are the basal factors to which generalizations and philosophies are but dependent accessories. We owe much of the transition itself to Dana and Le Conte, the two noblest American representatives of the passing type, for while they grew up under the influence of the older intellectual attitude, they grew out of it in spirit while they steadied and guided the transition. They were distinctively students of geology in the special sense in which that term implies the organized *doctrine* of the earth, rather than students of what might be termed *geics*, the immediate study of the earth itself in the field and the laboratory. They were preëminently students of the accumulated data and of the literature of the science, with generalization and philosophic inference as their dominant inspiration. Neither Dana nor Le Conte were eminently field students; much less were they specialists in a chosen field of the broad geological domain. Their point of view was that of the organizer and of the philosopher, and the contribution they made in their chosen sphere was indispensable and immeasurably valuable. How this necessary function is to be met in the future, with the increasing complexities and profundities into which every branch is rapidly growing, it is difficult to foresee, further than that it must in some way be intimately associated with extensive personal researches in the field and the laboratory, and must be guided by a reversal of the old-time attitude of philosophy and science toward each other. The philosophical factor must be put into service as the active handmaid of scientific determination rather than as its guide and leader. It may indeed go before as scout to roughly reconnoiter the way, and it may come after to assemble and interpret the results, but it must ever be tentative and dependent on rigorous scientific determination. Deduction, inference, interpretation, theory, hypothesis, and the other philosophical factors must be merely initial steps and sequential steps attendant on rigorous science as the end. None the less, the philosophical factors and the philosophical point of view are indispensable if the science is to make its most wholesome progress, and we owe to Le Conte and to those he typifies an immeasurable debt, for they have kept us in fresh touch with the generalizations and the philosophy of the science, and have inspired us with their own contributions to the broader conceptions of geology and of its relations to kindred sciences. The writings of Le Conte are graced by the fruits of wide learning, a lucid style, a genial attitude, and a candor that has called forth universal love and admiration. T. C. C.

THE progress of opinion in regard to the origin of the solar system, and incidentally of the earth, is indicated by the following recent utterances of astronomers of high rank :

> This simple hypothesis (Laplace's nebular hypothesis) has recently been severely attacked, and it is doubtful whether it will survive the blow. Indeed, we may be compelled to seek the origin of stellar systems in the spiral nebulae, which Keeler's photographic survey made just before his death showed to represent a true type form. It is evident that much remains to be done before the mystery which surrounds the genesis of stars can be cleared away.— PROFESSOR GEORGE E. HALE, Director Yerkes Observatory, in address to Visiting Committee, *University Record*, June 28, 1901, p. 141.
>
> Though, without doubt, the system was evolved in some way from a primitive nebula, we may say with certainty that it did not follow the orderly course marked out for it by Laplace.— PROFESSOR C. L. DOOLITTLE, of the University of Pennsylvania, in annual address delivered before the University of Pennsylvania chapters of the Society of Sigma Xi, June 13, 1901, printed in *Science*, July 5, 1901, pp. 11-12.

REVIEWS

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

WALCOTT[2] reports on the results of an examination of Cambrian and pre-Cambrian formations on Smith's Sound, Newfoundland, during the summer of 1899. At Smith point he found the Olenellus fauna 369 feet below the summit of the Etcheminian, and one of its types, Coleoloides typicalis, in the basal bed of the Cambrian, on the south side of Random Island. This retains the Etcheminian of Newfoundland in the Lower Cambrian.

The Random terrane, so-called from a typical section on Random Sound, is a series of sandstones, quartzitic sandstones, and sandy shales, resting conformably upon the Signal Hill conglomerate (which was formerly supposed to represent the top of the Avalon or Algonkian series) and extending up to the base of the Cambrian. The Random terrane is thus the upper member of the Avalon series and fills a portion, if not all, of the gap between the Signal Hill conglomerate and the Cambrian. The Cambrian rests on the Random terrane with a thin belt of conglomerate. The thickness of the terrane is probably 1000 feet. In one horizon in the terrane were found several varieties of annelid trails, including a variety about 5 millimeters broad, a slender form ½ millimeter broad, and an annulated trail 2 to 3 millimeters in width.

An examination of the form known as Aspidella terranovica found in the Momable terrane of the Avalon series proved the supposed fossil to be a spherulitic concretion, and this removes it from among the possible pre-Cambrian forms of life.

Cushing[3] describes and maps the pre-Cambrian rocks of Franklin county, New York. These are classified as Grenville (Algonkian) rocks, igneous rocks intrusive in the Grenville, and other igneous rocks of doubtful age, possibly in part older than the Grenville rocks.

---

[1] Continued from p. 87, Vol. IX, this JOURNAL.

[2] Random, A Pre-Cambrian Upper Algonkian Terrane, by CHARLES D. WALCOTT: Bulletin of the Geological Society of America, Vol. XI, 1900, pp. 3–5.

[3] Preliminary Report on the geology of Franklin county, Pt. III, by H. P. CUSHING: Eighteenth Annual Report of the State Geologist of the State of New York, 1900, pp. 75–128. With geological map.

The Grenville rocks occur in small disconnected patches surrounded by intrusive igneous rocks. Some of them have such position with reference to one another that they seem to represent remnants of what were originally two continuous parallel N. E. to S. W. belts. The characteristic rock of the series is the crystalline marble. This is intricately infolded with quartzose and hornblendic gneisses, and with fine-grained granitic, syenitic, and gabbroic gneisses precisely like gneisses which occur in other areas where no member of the Grenville series is to be found.

The gneisses of undetermined age include granite, syenite, diorite, and gabbro gneisses, together with intermediate varieties. They occupy a very large area. If all these gneisses are igneous (as is thought probable) there are three possibilities in regard to their age.

1. They may represent in whole or part a more ancient series than the Grenville.

2. They may represent a somewhat later series intrusive in the Grenville, but older than the great gabbro, syenite, and granite intrusions.

3. They may represent thoroughly foliated phases of these later intrusions.

In Dr. Cushing's present judgment they will be found to belong partly under 2 and partly under 3, but more especially the former.

No rocks have been found in the northern Adirondacks which can be shown to be older than the Grenville series, but in every case in which the relations have been made out, the adjacent rocks show intrusive contacts with the Grenville rocks. On the other hand, the Grenville is a sedimentary series and must have been laid down on some floor.

Younger than the Grenville rocks and for the most part younger than the doubtful gneisses are a considerable quantity of igneous rocks comprising gabbros (anorthosites) syenites, and granites. These again occupy large areas.

In the northern portion of the county, Upper Cambrian rocks overlie the pre-Cambrian rocks with unconformity.

Smyth[1] discusses certain features of recent work in the western

---

[1] The Crystalline Rocks of Western Adirondack Region, by C. H. SMYTH: Rept. of the New York State Geologist for 1897, published in Fifty-first Ann. Rept. of New York State Museum, Vol. II, 1899, pp. 469–467.

Adirondack region. He concludes that the rock previously called gabbro by Nason, Van Hise, Williams, and himself, south of the belt of limestone in the Diana-Pitcairn area in Lewis and St. Lawrence counties, is an augite syenite of igneous origin, although it passes into a hornblende-gneiss which is unquestionably a result of dynamic action. The origin of other gneisses has been inferred to be igneous from their similarity to this gneiss which has been particularly studied, and it is evidence of this kind which serves as a basis for Smyth's conclusions, previously published,[1] that some of the gneisses on the western Adirondacks are certainly, and most of them probably, of igneous origin.

With the view of exploring the central and little known portion of the Adirondacks, a reconnaissance was made through the area contiguous to the Fulton chain of lakes and Raquette Lake in the counties of Hamilton and Herkimer. It was found that the heart of the Adirondacks is made up essentially of gneiss, with minor quantities of crystalline limestone and its associated sedimentary gneisses and schists. This is precisely analogous to what was found by the writer in St. Lawrence, Jefferson, Northern Lewis, and southwestern Hamilton counties, and by Kemp and Cushing in the eastern Adirondacks. These facts lead to the conclusion that the Adirondack region, instead of consisting of a great central mass of gabbro, surrounded by a narrow fringe of gneisses and limestones with quaquaversal dip, is essentially composed of gneisses, with numerous limestone belts, having northeast strike, and northward dip, and cut through on the east by immense intrusions of gabbro. It is still possible, of course, that some areas of gabbro may be found in the unexplored portions of the western half, but even should this be so, it would not materially modify the above conclusion, as such masses must necessarily be isolated intrusions of no great extent, rather than parts of a large area.

Kemp,[2] in connection with the description of the magnetite deposits of the Adirondacks, briefly describes the general features of the geology of the gabbro and gneiss of Westport, Elizabethtown, and Newcomb townships in Essex county, New York, and presents a geological map of the former two townships.

---

[1] See Summary JOUR. GEOL., Vol. VII, p. 406.

[2] The Titaniferous Iron Ores of the Adirondacks, by J. F. KEMP: Nineteenth Ann. Rept. U. S. Geol. Surv., 1897-8, Pt. III, 1899, pp. 397-399.

Kemp and Newland[1] make a preliminary report on the geology of Washington, Warren, and parts of Essex and Hamilton counties, New York. Some of the points particularly noted are:

The excessive mashing and granulation of the gneisses, giving them in places semblance to quartzite. The greenish gneisses, consisting in largest part of microperthite, were originally eruptive rocks. The discovery is reported of quartzose gneisses or foliated quartzites which are certainly metamorphosed sediments. They form notable areas along the head of South Bay, Whitehall township. Their presence indicates the probable presence of a considerable series of clastic sediments. The crystalline limestones themselves have been found in small exposures over almost all of Warren county, and generally in the crystalline belt of Washington. They are most extensive in Newcomb and Minerva townships of Essex, and to the south become thinner and more scattered. So far as we have observed they are less common in eastern Hamilton county. There is evidence to show that stratigraphical relations can be proven and that anticlines and synclines can be demonstrated.

Dikes of basic gabbro usually of moderate width, but lithologically like the larger masses in Essex county, have been met over a wide area — in fact almost every township in Warren, but the basaltic traps almost disappear.

Kemp[2] summarizes the present knowledge of the pre-Cambrian rocks of the Adirondacks. Most of the features have been covered in previous articles. Attention is called to the distribution of the sedimentary crystalline rocks, the Oswegatchie series (equivalent to the Grenville series of Adams and perhaps the Huronian). These consist of limestones, sedimentary gneisses, and quartzites. They occupy greater area than has been supposed. The limestones are found chiefly in the northwest, and the southeast or eastern portions of the Adirondack area of crystalline rocks. They are in small quantity, or altogether absent in the northern portion, in the broad belt running from

northeast to southwest across the area, and along the southern and southwestern border. On the northwest they are in extended and comparatively broad belts, but in the eastern portion they appear in many small and separated exposures, associated with some quartzites and much greater amounts of characteristic gniesses, but greatly broken up by igneous intrusions. The quartzites thus far known are in small quantity, but such as they are, they are found principally in the eastern portions of the area, where the limestones are thinnest and most scattered. From the presence of the quartzites it is inferred that clastic sediments must have been present in larger amounts than has heretofore been realized. On the east it has not been proven that sediments form synclines pinched into the underlying gneissoid rocks. On the contrary they seem to constitute low, dipping, flat monoclines.

---

[1] Preliminary Rept. on the Geology of Washington, Warren, parts of Essex and Hamilton counties, by J. F. KEMP and D. H. NEWLAND: Rept. of the New York State Geologist for 1897, published in Fifty-first Ann. Rept., New York State Museum, Vol. II, 1899, pp. 499–553.

[2] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in the Proceedings of the A. A. A. S., Vol. XLIX, 1900, pp. 157–184.

Comment.—The complex geology of the Adirondack crystalline rocks is being rapidly worked out by Kemp, Smyth, Cushing, and others. The frequent brief papers issued by these geologists in nearly all cases report some important advance in the solution of their problem. The precise relations of these advances to the general problem may not be clear to the average geological reader, too busily engaged to follow the subject closely, and for such the general summary of Adirondack geology given by Kemp[1] will be of value.

In a previous comment[2] on Adirondack geology the state of geological knowledge, as indicated by the literature on the subject then available, was briefly summarized by the writer, and here attention will be called only to later developments. One of the most interesting of these is the extension of the areas of pre-Cambrian sedimentary and associated rocks, and the corresponding contraction in the area of the great Adirondack gabbro. This was formerly supposed to occupy the great central area of the Adirondacks with the pre-Cambrian sediments and the associated gneisses around its periphery. Recent work seems to show that the area is occupied by gneisses, with narrow limestone belts, cut through on the east by a number of immense intrusions of gabbro. Another advance is the discovery of greater quantities of clastic sediment than have before

been realized in the eastern portion of the Adirondack area, where the limestone is thinnest. The main problem of the region, the origin of the gneisses, is as yet far from settlement. The tendency is, however, to ascribe to them an igneous origin, and to place them later than the Oswegatchie series, in the areas where they have been most closely studied.

---

[1] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in Proceedings of the A. A. A. S., Vol. XLIX. 1900, pp. 157-184.

[2] JOUR. GEOL., Vol. VII, pp. 410-411.

Jones,[1] in connection with a description of Tallulah Gorge of northeastern Georgia, describes the crystalline rocks there occurring, and gives a little sketch map showing their relations. They are called pre-Cambrian.

Watson[2] describes the granitic rocks of the Piedmont plateau of Georgia. Field and laboratory studies indicate that they are not all contemporaneous in origin. Some of them are pre-Cambrian, while others may possibly be later in age.

Adams[3] describes the Laurentian granitoid gneiss and granite of the Admiralty group of the Thousand Islands, Ontario. The granitoid gneiss is presumably derived by metamorphism from the granite. A large exposure of crystalline limestone on Island No. 18 resembles in all respects that of the Grenville series of the mainland adjacent.

Parks[4] describes the geology of the Moose River Basin in Canada, including the Moose and Abitibi Rivers, tributary to James Bay. This is an immense triangular area of which the apex is at James Bay, and the base stretches from above Lake Abitibi to a point west of Kabinakagami. The southern and major portion of this triangular area consists of Laurentian gneisses and granites crossed, by bands of Huronian rocks. Along the Abitibi River, Huronian rocks, consisting of altered diorites, pyrites, gray quartz schists, and some soft decomposed schists occupy the country to the south, extending as far north as the head of the first long rapid on the Frederick House River. The line of contact of this belt crosses the Abitibi below the Iroquois

---

[1] The Geology of the Tallulah Gorge, by S. P. JONES: American Geologist, Vol. XXVII, 1901, pp. 67–75.

[2] The Granitic Rocks of Georgia and Their Relationships, by T. L. WATSON: American Geologist, Vol. XXVII, 1901, pp. 223–225.

[3] Notes on the Geology of the Admiralty Group of the Thousand Islands, by FRANK D. ADAMS: Can. Rec. of Sci., Vol. VII, 1897, pp. 267–272.

[4] PARKS, WILLIAM A.: The Nipissing Algoma boundary, Eighth Rept. Ont. Bur. Mines, 1899, pp. 175–204, with geological map; Niven's base line, Ninth Rept. Ont. Bur. Mines, 1900, pp. 125–142; The Huronian of the Moose River Basin, University of Toronto Studies, Geol. Series No. 1, 1900, pp. 35, with sketch map.

Falls. From this point to the Lobstick portage, Laurentian gneisses and mica schists crop out occasionally. The narrow Huronian belt from the Lobstick to the foot of the canyon or Long Portage, consists mainly of augite-syenite, passing into gabbro to the north. Beyond this portage Laurentian gneiss extends to the Devonian contact above the Sextant rapids.

Coleman[1] gives a general account of a visit to all the iron and copper regions of the Lake Superior country. For the ranges on the United States side of the boundary no facts are given not found in the published reports. On the Canadian side of the boundary the Michipicoten Range, the iron formation near Dog River, and the siliceous iron ores of Batchawana Bay are described. In the Michipicoten range the Helen mine in particular is referred to. In general, the rocks, including the ore at this mine, have all the appearance of Lower Huronian or Keewatin rocks, as in the Vermilion district, and not those of the Upper Huronian or Animikie, as in the Mesaba.

Near Dog River are iron formation rocks similar to those extending northeast from Michipicoten bay. It is thought probable that the two may connect.

The occurrence and relations of iron formation material northeast from Michipicoten Bay and near Dog River are indicated on a sketch map.

Coleman,[2] as a result of an examination of the new Michipicoten iron district, and the consideration of other iron formation areas in Ontario, has collected facts which seem to throw some light on the relative ages of the different areas mapped as Huronian on the north shore. In the Michipicoten district iron-formation material, consisting of banded ferruginous sandstones, cherts, and jaspers, standing nearly vertical, extends from Little Gros Cap northeastward for twenty miles; then bending to the north and west it takes a westerly direction for more than thirty miles. The width of the belt is but a few hundred yards.

Sandstones of the same peculiar type occur at Little Turtle Lake, east of Rainy Lake and near Fort Frances, on Rainy River, as well as at the Scramble gold mine, near Rat Portage, on Lake of the Woods.

---

[1] COLEMAN, DR. A. P.: Copper and Iron Regions of Ontario, by A. P. COLEMAN. Report of the Ontario Bureau of Mines for 1900, pp. 143–191.

[2] Upper and Lower Huronian in Ontario, by ARTHUR P. COLEMAN: Bull. Geol. Soc. Am., Vol. II, 1900, pp. 107–114.

Kemp and Newland[1] make a preliminary report on the geology of Washington, Warren, and parts of Essex and Hamilton counties, New York. Some of the points particularly noted are:

The excessive mashing and granulation of the gneisses, giving them in places semblance to quartzite. The greenish gneisses, consisting in largest part of microperthite, were originally eruptive rocks. The discovery is reported of quartzose gneisses or foliated quartzites which are certainly metamorphosed sediments. They form notable areas along the head of South Bay, Whitehall township. Their presence indicates the probable presence of a considerable series of clastic sediments. The crystalline limestones themselves have been found in small exposures over almost all of Warren county, and generally in the crystalline belt of Washington. They are most extensive in Newcomb and Minerva townships of Essex, and to the south become thinner and more scattered. So far as we have observed they are less common in eastern Hamilton county. There is evidence to show that stratigraphical relations can be proven and that anticlines and synclines can be demonstrated.

Dikes of basic gabbro usually of moderate width, but lithologically like the larger masses in Essex county, have been met over a wide area — in fact almost every township in Warren, but the basaltic traps almost disappear.

Kemp[2] summarizes the present knowledge of the pre-Cambrian rocks of the Adirondacks. Most of the features have been covered in previous articles. Attention is called to the distribution of the sedimentary crystalline rocks, the Oswegatchie series (equivalent to the Grenville series of Adams and perhaps the Huronian). These consist of limestones, sedimentary gneisses, and quartzites. They occupy greater area than has been supposed. The limestones are found chiefly in the northwest, and the southeast or eastern portions of the Adirondack area of crystalline rocks. They are in small quantity, or altogether absent in the northern portion, in the broad belt running from

northeast to southwest across the area, and along the southern and southwestern border. On the northwest they are in extended and comparatively broad belts, but in the eastern portion they appear in many small and separated exposures, associated with some quartzites and much greater amounts of characteristic gniesses, but greatly broken up by igneous intrusions. The quartzites thus far known are in small quantity, but such as they are, they are found principally in the eastern portions of the area, where the limestones are thinnest and most scattered. From the presence of the quartzites it is inferred that clastic sediments must have been present in larger amounts than has heretofore been realized. On the east it has not been proven that sediments form synclines pinched into the underlying gneissoid rocks. On the contrary they seem to constitute low, dipping, flat monoclines.

---

[1] Preliminary Rept. on the Geology of Washington, Warren, parts of Essex and Hamilton counties, by J. F. KEMP and D. H. NEWLAND: Rept. of the New York State Geologist for 1897, published in Fifty-first Ann. Rept., New York State Museum, Vol. II, 1899, pp. 499–553.

[2] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in the Proceedings of the A. A. A. S., Vol. XLIX, 1900, pp. 157–184.

Comment.—The complex geology of the Adirondack crystalline rocks is being rapidly worked out by Kemp, Smyth, Cushing, and others. The frequent brief papers issued by these geologists in nearly all cases report some important advance in the solution of their problem. The precise relations of these advances to the general problem may not be clear to the average geological reader, too busily engaged to follow the subject closely, and for such the general summary of Adirondack geology given by Kemp[1] will be of value.

In a previous comment[2] on Adirondack geology the state of geological knowledge, as indicated by the literature on the subject then available, was briefly summarized by the writer, and here attention will be called only to later developments. One of the most interesting of these is the extension of the areas of pre-Cambrian sedimentary and associated rocks, and the corresponding contraction in the area of the great Adirondack gabbro. This was formerly supposed to occupy the great central area of the Adirondacks with the pre-Cambrian sediments and the associated gneisses around its periphery. Recent work seems to show that the area is occupied by gneisses, with narrow limestone belts, cut through on the east by a number of immense intrusions of gabbro. Another advance is the discovery of greater quantities of clastic sediment than have before

been realized in the eastern portion of the Adirondack area, where the limestone is thinnest. The main problem of the region, the origin of the gneisses, is as yet far from settlement. The tendency is, however, to ascribe to them an igneous origin, and to place them later than the Oswegatchie series, in the areas where they have been most closely studied.

---

[1] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in Proceedings of the A. A. A. S., Vol. XLIX, 1900, pp. 157–184.

[2] JOUR. GEOL., Vol. VII, pp. 410–411.

Jones,[1] in connection with a description of Tallulah Gorge of northeastern Georgia, describes the crystalline rocks there occurring, and gives a little sketch map showing their relations. They are called pre-Cambrian.

Watson[2] describes the granitic rocks of the Piedmont plateau of Georgia. Field and laboratory studies indicate that they are not all contemporaneous in origin. Some of them are pre-Cambrian, while others may possibly be later in age.

Adams[3] describes the Laurentian granitoid gneiss and granite of the Admiralty group of the Thousand Islands, Ontario. The granitoid gneiss is presumably derived by metamorphism from the granite. A large exposure of crystalline limestone on Island No. 18 resembles in all respects that of the Grenville series of the mainland adjacent.

Parks[4] describes the geology of the Moose River Basin in Canada, including the Moose and Abitibi Rivers, tributary to James Bay. This is an immense triangular area of which the apex is at James Bay, and the base stretches from above Lake Abitibi to a point west of Kabinakagami. The southern and major portion of this triangular area consists of Laurentian gneisses and granites crossed, by bands of Huronian rocks. Along the Abitibi River, Huronian rocks, consisting of altered diorites, pyrites, gray quartz schists, and some soft decomposed schists occupy the country to the south, extending as far north as the head of the first long rapid on the Frederick House River. The line of contact of this belt crosses the Abitibi below the Iroquois

---

[1] The Geology of the Tallulah Gorge, by S. P. JONES: American Geologist, Vol. XXVII, 1901, pp. 67–75.

[2] The Granitic Rocks of Georgia and Their Relationships, by T. L. WATSON: American Geologist, Vol. XXVII, 1901, pp. 223–225.

[3] Notes on the Geology of the Admiralty Group of the Thousand Islands, by FRANK D. ADAMS: Can. Rec. of Sci., Vol. VII, 1897, pp. 267–272.

[4] PARKS, WILLIAM A.: The Nipissing-Algoma boundary, Eighth Rept. Ont. Bur. Mines, 1899, pp. 175–204, with geological map; Niven's base line, Ninth Rept. Ont. Bur. Mines, 1900, pp. 125–142; The Huronian of the Moose River Basin, University of Toronto Studies, Geol. Series No. 1, 1900, pp. 35, with sketch map.

Falls. From this point to the Lobstick portage, Laurentian gneisses and mica schists crop out occasionally. The narrow Huronian belt from the Lobstick to the foot of the canyon or Long Portage, consists mainly of augite-syenite, passing into gabbro to the north. Beyond this portage Laurentian gneiss extends to the Devonian contact above the Sextant rapids.

Coleman[1] gives a general account of a visit to all the iron and copper regions of the Lake Superior country. For the ranges on the United States side of the boundary no facts are given not found in the published reports. On the Canadian side of the boundary the Michipicoten Range, the iron formation near Dog River, and the siliceous iron ores of Batchawana Bay are described. In the Michipicoten range the Helen mine in particular is referred to. In general, the rocks, including the ore at this mine, have all the appearance of Lower Huronian or Keewatin rocks, as in the Vermilion district, and not those of the Upper Huronian or Animikie, as in the Mesaba.

Near Dog River are iron formation rocks similar to those extending northeast from Michipicoten bay. It is thought probable that the two may connect.

The occurrence and relations of iron formation material northeast from Michipicoten Bay and near Dog River are indicated on a sketch map.

Coleman,[2] as a result of an examination of the new Michipicoten iron district, and the consideration of other iron formation areas in Ontario, has collected facts which seem to throw some light on the relative ages of the different areas mapped as Huronian on the north shore. In the Michipicoten district iron-formation material, consisting of banded ferruginous sandstones, cherts, and jaspers, standing nearly vertical, extends from Little Gros Cap northeastward for twenty miles; then bending to the north and west it takes a westerly direction for more than thirty miles. The width of the belt is but a few hundred yards.

Sandstones of the same peculiar type occur at Little Turtle Lake, east of Rainy Lake and near Fort Frances, on Rainy River, as well as at the Scramble gold mine, near Rat Portage, on Lake of the Woods.

---

[1] COLEMAN, DR. A. P.: Copper and Iron Regions of Ontario, by A. P. COLEMAN. Report of the Ontario Bureau of Mines for 1900, pp. 143–191.

[2] Upper and Lower Huronian in Ontario, by ARTHUR P. COLEMAN: Bull. Geol. Soc. Am., Vol. II, 1900, pp. 107–114.

Thin sections of these rocks show the same polygonal shapes of the grains of quartz, and more or less iron ore is associated with specimens from each locality. It is very probable, then, that the same horizon exists at points far to the west of Lake Superior.

Turning toward the east, specimens very like the jaspery varieties of the Michipicoten iron range are found interbedded with iron ores near Lakes Wahnapitae and Temagami, between Sudbury and the Ottawa River.

At Batchawana Bay at the southeast end of Lake Superior, a siliceous rock with narrow bands of magnetite occurs, which is probably the equivalent of the Michipicoten rock.

If, as seems probable, these jaspers are the equivalents of the western Huronian sandstones, there is a definite horizon traceable from point to point across the whole northern end of the province, a distance of more than six hundred miles.

At a number of places over this area conglomerates, containing jasper, ferruginous sandstone or chert pebbles, probably derived from the source above described, are known. Beginning at the west, some of these conglomerates occur as follows: on Shoal Lake, east of Rainy Lake; west end of Schist Lake; near Mosher Bay, at the east end of Upper Manitou Lake; a mile east of Fort Frances on the Rainy River; near Rat Portage; near the mouth of Dorè River; in the original Huronian area, north of Lake Huron, particularly the Thessalon area; on Lake Temiscaming.

It is assumed that the iron-formation material cannot be other than Lower Huronian, and that the conglomerates must represent a basal horizon of the Upper Huronian. The break between the Upper and Lower Huronian thus represented is a most profound one, and affords a good basis for the correlation of the Huronian formations. It is further suggested that this great unconformity may be the same as that between the Upper and Lower Huronian formations on the south shore of Lake Superior and in Minnesota.

Comment.—As stated by Dr. Coleman a number of the conglomerates above mentioned have been regarded by Pumpelly, Irving, Van Hise, and other United States geologists, as basal to the Lower Huronian—on structural evidence. Dr. Coleman places them in the Upper Huronian because they contain fragments of iron formation material which are assumed to be Lower Huronian. According to the generally accepted ideas of the number and relations of the pre-Cambrian iron bearing formations, this assumption is perfectly justified and the conclusion follows as to the Upper Huronian age of the typical conglomerates mentioned.

But, lately evidence has been accumulated pointing to a conclusion of a rather radical nature. This evidence has been such that Van Hise[1] in a general article on the iron bearing formations of the Lake Superior country just published, describes *three* iron bearing formations, the Upper Huronian, Lower Huronian, and *Archean*. The most important of the Archean iron bearing formations are the Vermilion and the Michipicoten.

Van Hise himself in his published articles on the pre-Cambrian has persistently maintained the essentially non-clastic nature of the Archean, and the post-Archean age of all the iron bearing formations of the Lake Superior country. But new evidence on the subject, secured principally during the past year, has been so decisive that he has not hesitated to announce as proven the existence of an Archean or Basement Complex iron-bearing formation.

If there is an Archean iron formation, to which the Michipicoten and Vermilion iron formations belong, then Dr. Coleman's argument as to the Upper Huronian age of conglomerates containing iron formation fragments is rendered ineffective, and the conclusions indicated by the structural evidence that the great conglomerates and accompanying rocks above described are Lower Huronian must stand, until decisive evidence to the contrary is found.

Grant[2] describes and maps the Upper and Lower Keweenawan copper-bearing rocks of Douglas county, Wisconsin. The Lower Keweenawan appears in a broad belt running from northeast to southwest across the county, widening toward the southwest, and in a small belt cutting through the southeastern corner of the county. It consists mainly of basic lava flows, associated with which, in the area in the southeast corner of the county, are a few beds of conglomerate composed of débris of the closely adjacent underlying rocks. The Upper Keweenawan appears in a broad belt in the southeastern part of the county between the two belts of Lower Keweenawan rocks. It is a series of conglomerates, sandstones and shales. In a belt north of the northern belt of Lower Keweenawan rocks, extending from these rocks to the shore of Lake Superior, is the Lake Superior sandstone (Cambrian). This is either flat-lying or dips slightly toward Lake Superior. The junction of the sandstone with the Lower Keweenawan is marked by a fault, along which the Lake Superior sandstone has been depressed, in some places probably as much as several hundred feet.

---

[1] The iron-ore deposits of the Lake Superior region, by C. R. VAN HISE: Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, 1901, p. 322.

[2] Preliminary Report on Copper Bearing Rocks in Douglas county, Wisconsin, by U. S. GRANT: Wisconsin Geological and Natural History Survey, Vol. VI, 1900, pp. 55.

The Upper and Lower Keweenawan belts form a syncline, the axis of which runs northeast and southwest through the center of the tract underlain by Upper Keweenawan rocks.

While the Keweenawan rocks of this area are the same in kind and age as are the productive copper-bearing rocks of Keweenaw Point, the probable unproductive character of the Douglas county rocks is intimated.

Alexander Winchell[1] prefaces a detailed petrographical description of certain phases of the gabbroid rocks of Minnesota with a brief account of the general succession in structure of formations in northeastern Minnesota. This is essentially the same as given by N. H. Winchell[2] in Volumes IV and V of the Minnesota State Survey. The correlation of this succession with the succession determined by the United States Geological Survey is discussed.

Comment.—Mr. Winchell's ideas as to succession and structure determined by the United States Geological Survey are naturally derived mainly from Bulletin 86 of the Survey and from the "Principles of Pre-Cambrian Geology" published in the Sixteenth Annual Report of the Survey. However, since these reports have been issued, the United States Geological Survey has done somewhat detailed field work in northeastern Minnesota as a result of which the ideas of the United States geologists on the succession and correlation have been considerably changed. The new conclusions of the Survey are briefly outlined by Van Hise in the Twenty-first Annual Report. This paper should be referred to by anyone reading Mr. Winchell's discussion of the correlation.

[1] Mineralogical and Petrographic study of the gabbroid rocks of Minnesota, and more particularly of the plagioclastites, by ALEXANDER N. WINCHELL: American Geologist, Volume XXVI, 1900, General part, pp. 153–162, with geological sketch map of Northeastern Minnesota.

[2] See summaries, JOUR. GEOL., Vol. IX, pp. 79–86.

Van Hise and Bayley[1] describe and map the geology of a portion of the Menominee iron district of Michigan.

The pre-Cambrian succession is as follows:

Algonkian	Upper Menominee	Hanbury slate. Vulcan formation, subdivided into the Curry ore-bearing member, Brier slate, and Traders ore-bearing member.
	Unconformity	
	Lower Menominee	Negaunee formation. Randville dolomite. Sturgeon quartzite.
	Unconformity	
Archean	- - - - -	Granites and gneisses, cut by granite and diabase dikes. Quinnesec schists, cut by acid and basic dikes and veins.

In general the Algonkian rocks constitute a trough bounded on the north by the Archean rocks.

The Archean.— The Quinnesec schists are dark green or black basic schists and spheroidal greenstones, cut by large dikes of gabbro, diabase, and granite, and by smaller dikes of a schistose quartz porphyry. These occur in two areas, one along the Menominee River to the south of the Huronian rocks, and another in the west-central end of the district.

Bordering the Algonkian trough on the north is a complex of granites, gneisses, hornblende schists, and a few greenstone schists, all cut by dikes of diabase and granite. This complex is called the "Northern Complex." Most of the Archean rocks are igneous. Although there is no evidence of this, some of the fragmental tuffs may have been water-deposited. The Quinnesec schists and the Northern Complex are called Archean because they resemble lithologically other areas of Archean rocks in the Lake Superior country, and they both underlie the Algonkian series. The Northern Complex underlies the series with unconformity. The Quinnesec schists have not been observed in contact, and hence the presence or absence of a normal erosion unconformity cannot be inferred.

---

[1] The Menominee special folio, by CHARLES R. VAN HISE and S. W. BAYLEY: Geological Atlas of United States, Folio No. 62, U. S. Geol. Surv., 1900.

The Lower Menominee series.—The formations of the Lower Menominee series are observed only in the center and on the northern side of the Menominee trough. The Sturgeon formation is composed mainly of a hard white vitreous quartzite forming a continuous border of bare hills bordering the Archean complex. At its base is a coarse conglomerate made up of débris from the underlying Archean complex. The belt is in general a southward dipping monocline with dips varying from 25° to perpendicularity, although there are many reverse dips to the north. Its thickness is placed at from 1000 to 1250 feet.

Above, the Sturgeon quartzite grades into the Randville formation which is mainly a homogeneous dolomite interstratified with siliceous or argillaceous layers. This formation appears in three belts. The northern one is just south of the belt of the Sturgeon quartzite. The central belt is on the north side of Lake Antoine for a portion of its length, passes eastward between the Cuff and the Indiana mines, and ends at the bluff known as Iron Hill in the east half of Sec. 32, T. 40 N., R. 29 W. The southern belt of dolomite extends all the way from the western side of the sandstone bluff west of Iron Mountain to the village of Waucedah, at the eastern end of the mapped area. Structurally the northern belt of dolomite is a southward dipping monocline, while the two southern belts are anticlines. The thickness is not determined on satisfactory evidence, but is probably 1000 feet or more. The Randville formation is found, in a number of mines. in contact with the basal formation of the Upper Menominee series Here there is a coarse conglomerate in the basal part of the overlying formation indicating unconformity.

The Negaunee formation, overlying the Randville dolomite, is represented in the district by so few and so small outcrops that it is mapped with the Vulcan formation. Its presence is inferred mainly from the occurrence of abundant iron formation débris in the basal conglomerate of the Upper Menominee formation, showing that the Lower Menominee iron-bearing series must have been present. In the Marquette district an iron-bearing formation (the Negaunee) occupies an exactly similar stratigraphical position.

The Upper Menominee series.—The formations between the unconformity at the top of the Lower Menominee and the unconformity at the base of the Lake Superior sandstone, are placed in the Upper Menominee series. These occur in two great series, the Vulcan and the Hanbury.

The Vulcan formation is unconformable above the upper part of the Lower Huronian, which for most of the district is the Randville formation, and unconformable below the Hanbury slate. For parts of the district the Vulcan iron-bearing formation does not appear at all between the dolomite and the slate and its absence is explained by the unconformity between the Vulcan formation and the Hanbury slate. The Vulcan formation embraces three members. These are, from the base up, the Traders iron-bearing member, the Brier slate, and the Curry iron-bearing member. They are mapped as a single formation. The principal area of the Vulcan iron formation is in the belt 900 to 1300 feet wide, following the sinuosities of the southern border of the southern belt of Randville dolomite. It is generally absent north of the southern belt except at the east end where it appears at the Loretto mine and eastward. The second important area of Vulcan iron formation stretches off about five miles along the south side of the central dolomite belt running north of Lakes Antoine and Fumee, and ending somewhere about the east line of Range 30 West. At the east end of the dolomite area the iron-bearing formation appears in the lean slates at Iron Hill. The third stretch of country in which the iron-bearing beds are to be expected is that which borders the northern dolomite belt, but while pits have shown the existence of the formation here its distribution is unknown. The other areas in which the Vulcan formation may occur are those bordering the Quinnesec schists, but this has not yet been determined.

The Traders member consists of ferruginous conglomerate, ferruginous quartzite, heavily ferruginous quartzose slates and iron ore deposits. The Brier member consists of heavy black ferruginous and quartzose slates. The Curry member consists of interbedded japsilite, ferruginous quartzose slates and iron ore deposits. The relations of the Traders and Brier Hill members where there has been no disturbance of the strata is that of gradation. Where there has been disturbance, as in the vicinity of Norway, there has been a zone of differential movement between the two, resulting in slickensides and brecciated zones. Between the Brier slates and the Curry member there is gradation.

The Vulcan formation is bent into folds of several orders of

magnitude, the greater ones corresponding approximately to the folds in the underlying Randville dolomite. The total thickness of the formation is probably 600 to 700 feet.

The iron ore deposits of large size rest upon relatively impervious formations, which are in such positions as to constitute pitching troughs. A pitching trough may be made (*a*) by the dolomite formation underlying the Traders member of the Vulcan formations, (*b*) by a slate constituting the lower part of the Traders member, and (*c*) by the Brier slate between the Traders and Curry members of the Vulcan formation. The dolomite formation is especially likely to furnish an impervious basement where its upper horizon has been transformed into a talc-schist, as a consequence of folding and shearing between the formations.

Unconformably above the Vulcan iron formation is the Hanbury formation, which forms three large belts in the syncline of the older rocks, and occupies a very large proportion of the district. The formation comprises clay slates, calcareous slates, graphite slates, graywackes, quartzite, ferruginous dolomite, and rare bodies of ferruginous chert and iron oxide. The formation is much thicker than any of the other formations of the district, but it is probably not thicker than 2000 or 3000 feet.

Wilder[1] describes and maps the Sioux quartzites and quartz porphyries of Lyon county, Iowa. No points concerning the stratigraphy or age have been added to those already given by other writers.

Bain[2] describes the geology of the Wichita Mountains. Gabbros and porphyries of pre-Cambrian and probably of Archean age are present. The gabbro is more prominent in the western portion of the mountains, being especially well developed in the Raggedy Mountains, and the porphyry is more common in the eastern part of the mountains, being typically developed at Carrollton Mountain.

Matthews[3] gives a detailed petrographical description of the granites of the Pike's Peak quadrangle of Colorado. They are referred to the late Algonkian period.

---

[1] Geology of Lyon county, by FRANK A. WILDER: Iowa Geol. Surv., Vol. X, 1899, pp. 96–108.

[2] Geology of Wichita Mountains, by H. FOSTER BAIN: Bull. Geol. Soc. Am., Vol. XI, 1900, pp. 127–144, Pls. XV–XVII.

[3] The Granite Rocks of the Pike's Peak Quadrangle, by A. B. MATTHEWS: JOUR. GEOL., Vol. VIII, 1900, pp. 214–240.

Cross[1] maps and describes the geology of the Telluride quadrangle, Colorado, and briefly sketches the geology of the San Juan region, of which the Telluride quadrangle is a part.

In the Telluride quadrangle, along Canyon Creek north of Stony Mountain, is a small body of upturned quartzites, with an intercalated rhyolite sheet, which have been referred to the Algonkian. The quartzites are coarse and grade into fine conglomerate.

Ancient granites, gneisses, and schists are known in the Animas Valley and in the Uncompahgre plateau. These rocks have usually been considered as belonging to the Archean, but some of them are probably younger than the great series of quartzites exhibited in the Needle Mountains to the south, and younger than the quartzites beneath the volcanics in the canyons of the Uncompahgre, above Ouray, which have been referred to the Algonkian. These quartzites stand on edge or have been greatly disturbed. The relations of these isolated exposures to contemporaneous formations elsewhere are unknown.

Spurr[2] maps and briefly describes the Archean[3] granite of the Aspen district of Colorado. This is unconformably below and in direct contact with sediments of upper Cambrian age.

Davis[4] in a general account of a trip through the Colorado Canyon district briefly describes certain features of the pre-Cambrian geology. He calls attention to the extraordinary evenness of the floor of schists with granite dikes (Archean) upon which the Chuar and Unkar terranes (Algonkian) rest. The floor for the Paleozoic strata is somewhat less regular than the floor for the Unkar. In two places the pre-Cambrian rocks rise higher than the basal Tonto (Cambrian) sandstone. The Archean schists beneath the Unkar have a steep and regular slope, indicating uniform resistance to erosion. Where, beneath the Tonto, they show a bench, it is taken to indicate a softer character at this point, probably due to a longer period of pre-Tonto weathering.

---

[1] Telluride Folio, Colorado, by WHITMAN CROSS: Geol. Atlas of the U. S., No. 57, 1899.

[2] Geology of the Aspen Mining District, Colorado, with Atlas, by J. E. SPURR: Mon. U. S. Geol. Surv., No. 31, 1898, pp. 1–4.

[3] The term Archean is evidently used in the sense of pre-Cambrian.

[4] Notes on the Colorado Canyon District, by W. M. DAVIS: Am. Jour. Sci., 4th ser., Vol. X, 1900, pp. 251–259.

Kemp and Newland[1] make a preliminary report on the geology of Washington, Warren, and parts of Essex and Hamilton counties, New York. Some of the points particularly noted are:

The excessive mashing and granulation of the gneisses, giving them in places semblance to quartzite. The greenish gneisses, consisting in largest part of microperthite, were originally eruptive rocks. The discovery is reported of quartzose gneisses or foliated quartzites which are certainly metamorphosed sediments. They form notable areas along the head of South Bay, Whitehall township. Their presence indicates the probable presence of a considerable series of clastic sediments. The crystalline limestones themselves have been found in small exposures over almost all of Warren county, and generally in the crystalline belt of Washington. They are most extensive in Newcomb and Minerva townships of Essex, and to the south become thinner and more scattered. So far as we have observed they are less common in eastern Hamilton county. There is evidence to show that stratigraphical relations can be proven and that anticlines and synclines can be demonstrated.

Dikes of basic gabbro usually of moderate width, but lithologically like the larger masses in Essex county, have been met over a wide area — in fact almost every township in Warren, but the basaltic traps almost disappear.

Kemp[2] summarizes the present knowledge of the pre-Cambrian rocks of the Adirondacks. Most of the features have been covered in previous articles. Attention is called to the distribution of the sedimentary crystalline rocks, the Oswegatchie series (equivalent to the Grenville series of Adams and perhaps the Huronian). These consist of limestones, sedimentary gneisses, and quartzites. They occupy greater area than has been supposed. The limestones are found chiefly in the northwest, and the southeast or eastern portions of the Adirondack area of crystalline rocks. They are in small quantity, or altogether absent in the northern portion, in the broad belt running from

northeast to southwest across the area, and along the southern and southwestern border. On the northwest they are in extended and comparatively broad belts, but in the eastern portion they appear in many small and separated exposures, associated with some quartzites and much greater amounts of characteristic gniesses, but greatly broken up by igneous intrusions. The quartzites thus far known are in small quantity, but such as they are, they are found principally in the eastern portions of the area, where the limestones are thinnest and most scattered. From the presence of the quartzites it is inferred that clastic sediments must have been present in larger amounts than has heretofore been realized. On the east it has not been proven that sediments form synclines pinched into the underlying gneissoid rocks. On the contrary they seem to constitute low, dipping, flat monoclines.

---

[1] Preliminary Rept. on the Geology of Washington, Warren, parts of Essex and Hamilton counties, by J. F. KEMP and D. H. NEWLAND: Rept. of the New York State Geologist for 1897, published in Fifty-first Ann. Rept., New York State Museum, Vol. II, 1899, pp. 499–553.

[2] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in the Proceedings of the A. A. A. S., Vol. XLIX, 1900, pp. 157–184.

Comment.—The complex geology of the Adirondack crystalline rocks is being rapidly worked out by Kemp, Smyth, Cushing, and others. The frequent brief papers issued by these geologists in nearly all cases report some important advance in the solution of their problem. The precise relations of these advances to the general problem may not be clear to the average geological reader, too busily engaged to follow the subject closely, and for such the general summary of Adirondack geology given by Kemp[1] will be of value.

In a previous comment[2] on Adirondack geology the state of geological knowledge, as indicated by the literature on the subject then available, was briefly summarized by the writer, and here attention will be called only to later developments. One of the most interesting of these is the extension of the areas of pre-Cambrian sedimentary and associated rocks, and the corresponding contraction in the area of the great Adirondack gabbro. This was formerly supposed to occupy the great central area of the Adirondacks with the pre-Cambrian sediments and the associated gneisses around its periphery. Recent work seems to show that the area is occupied by gneisses, with narrow limestone belts, cut through on the east by a number of immense intrusions of gabbro. Another advance is the discovery of greater quantities of clastic sediment than have before

been realized in the eastern portion of the Adirondack area, where the limestone is thinnest. The main problem of the region, the origin of the gneisses, is as yet far from settlement. The tendency is, however, to ascribe to them an igneous origin, and to place them later than the Oswegatchie series, in the areas where they have been most closely studied.

---

[1] Pre-Cambrian Sediments in the Adirondacks, by J. F. KEMP: Vice Presidential address published in Proceedings of the A. A. A. S., Vol. XLIX, 1900, pp. 157–184.

[2] JOUR. GEOL., Vol. VII, pp. 410–411.

Jones,[1] in connection with a description of Tallulah Gorge of northeastern Georgia, describes the crystalline rocks there occurring, and gives a little sketch map showing their relations. They are called pre-Cambrian.

Watson[2] describes the granitic rocks of the Piedmont plateau of Georgia. Field and laboratory studies indicate that they are not all contemporaneous in origin. Some of them are pre-Cambrian, while others may possibly be later in age.

Adams[3] describes the Laurentian granitoid gneiss and granite of the Admiralty group of the Thousand Islands, Ontario. The granitoid gneiss is presumably derived by metamorphism from the granite. A large exposure of crystalline limestone on Island No. 18 resembles in all respects that of the Grenville series of the mainland adjacent.

Parks[4] describes the geology of the Moose River Basin in Canada, including the Moose and Abitibi Rivers, tributary to James Bay. This is an immense triangular area of which the apex is at James Bay, and the base stretches from above Lake Abitibi to a point west of Kabinakagami. The southern and major portion of this triangular area consists of Laurentian gneisses and granites crossed, by bands of Huronian rocks. Along the Abitibi River, Huronian rocks, consisting of altered diorites, pyrites, gray quartz schists, and some soft decomposed schists occupy the country to the south, extending as far north as the head of the first long rapid on the Frederick House River. The line of contact of this belt crosses the Abitibi below the Iroquois

---

[1] The Geology of the Tallulah Gorge, by S. P. JONES: American Geologist, Vol. XXVII, 1901, pp. 67–75.

[2] The Granitic Rocks of Georgia and Their Relationships, by T. L. WATSON: American Geologist, Vol. XXVII, 1901, pp. 223–225.

[3] Notes on the Geology of the Admiralty Group of the Thousand Islands, by FRANK D. ADAMS: Can. Rec. of Sci., Vol. VII, 1897, pp. 267–272.

[4] PARKS, WILLIAM A.: The Nipissing-Algoma boundary, Eighth Rept. Ont. Bur. Mines, 1899, pp. 175–204, with geological map; Niven's base line, Ninth Rept. Ont. Bur. Mines, 1900, pp. 125–142; The Huronian of the Moose River Basin, University of Toronto Studies, Geol. Series No. 1, 1900, pp. 35, with sketch map.

Falls. From this point to the Lobstick portage, Laurentian gneisses and mica schists crop out occasionally. The narrow Huronian belt from the Lobstick to the foot of the canyon or Long Portage, consists mainly of augite-syenite, passing into gabbro to the north. Beyond this portage Laurentian gneiss extends to the Devonian contact above the Sextant rapids.

Coleman[1] gives a general account of a visit to all the iron and copper regions of the Lake Superior country. For the ranges on the United States side of the boundary no facts are given not found in the published reports. On the Canadian side of the boundary the Michipicoten Range, the iron formation near Dog River, and the siliceous iron ores of Batchawana Bay are described. In the Michipicoten range the Helen mine in particular is referred to. In general, the rocks, including the ore at this mine, have all the appearance of Lower Huronian or Keewatin rocks, as in the Vermilion district, and not those of the Upper Huronian or Animikie, as in the Mesaba.

Near Dog River are iron formation rocks similar to those extending northeast from Michipicoten bay. It is thought probable that the two may connect.

The occurrence and relations of iron formation material northeast from Michipicoten Bay and near Dog River are indicated on a sketch map.

Coleman,[2] as a result of an examination of the new Michipicoten iron district, and the consideration of other iron formation areas in Ontario, has collected facts which seem to throw some light on the relative ages of the different areas mapped as Huronian on the north shore. In the Michipicoten district iron-formation material, consisting of banded ferruginous sandstones, cherts, and jaspers, standing nearly vertical, extends from Little Gros Cap northeastward for twenty miles; then bending to the north and west it takes a westerly direction for more than thirty miles. The width of the belt is but a few hundred yards.

Sandstones of the same peculiar type occur at Little Turtle Lake, east of Rainy Lake and near Fort Frances, on Rainy River, as well as at the Scramble gold mine, near Rat Portage, on Lake of the Woods.

---

[1] COLEMAN, DR. A. P.: Copper and Iron Regions of Ontario, by A. P. COLEMAN. Report of the Ontario Bureau of Mines for 1900, pp. 143–191.

[2] Upper and Lower Huronian in Ontario, by ARTHUR P. COLEMAN: Bull. Geol. Soc. Am., Vol. II, 1900, pp. 107–114.

Thin sections of these rocks show the same polygonal shapes of the grains of quartz, and more or less iron ore is associated with specimens from each locality. It is very probable, then, that the same horizon exists at points far to the west of Lake Superior.

Turning toward the east, specimens very like the jaspery varieties of the Michipicoten iron range are found interbedded with iron ores near Lakes Wahnapitae and Temagami, between Sudbury and the Ottawa River.

At Batchawana Bay at the southeast end of Lake Superior, a siliceous rock with narrow bands of magnetite occurs, which is probably the equivalent of the Michipicoten rock.

If, as seems probable, these jaspers are the equivalents of the western Huronian sandstones, there is a definite horizon traceable from point to point across the whole northern end of the province, a distance of more than six hundred miles.

At a number of places over this area conglomerates, containing jasper, ferruginous sandstone or chert pebbles, probably derived from the source above described, are known. Beginning at the west, some of these conglomerates occur as follows: on Shoal Lake, east of Rainy Lake; west end of Schist Lake; near Mosher Bay, at the east end of Upper Manitou Lake; a mile east of Fort Frances on the Rainy River; near Rat Portage; near the mouth of Dorè River; in the original Huronian area, north of Lake Huron, particularly the Thessalon area; on Lake Temiscaming.

It is assumed that the iron-formation material cannot be other than Lower Huronian, and that the conglomerates must represent a basal horizon of the Upper Huronian. The break between the Upper and Lower Huronian thus represented is a most profound one, and affords a good basis for the correlation of the Huronian formations. It is further suggested that this great unconformity may be the same as that between the Upper and Lower Huronian formations on the south shore of Lake Superior and in Minnesota.

Comment.—As stated by Dr. Coleman a number of the conglomerates above mentioned have been regarded by Pumpelly, Irving, Van Hise, and other United States geologists, as basal to the Lower Huronian—on structural evidence. Dr. Coleman places them in the Upper Huronian because they contain fragments of iron formation material which are assumed to be Lower Huronian. According to the generally accepted ideas of the number and relations of the pre-Cambrian iron bearing formations, this assumption is perfectly justified and the conclusion follows as to the Upper Huronian age of the typical conglomerates mentioned.

But, lately evidence has been accumulated pointing to a conclusion of a rather radical nature. This evidence has been such that Van Hise[1] in a general article on the iron bearing formations of the Lake Superior country just published, describes *three* iron bearing formations, the Upper Huronian, Lower Huronian, and *Archean*. The most important of the Archean iron bearing formations are the Vermilion and the Michipicoten.

Van Hise himself in his published articles on the pre-Cambrian has persistently maintained the essentially non-clastic nature of the Archean, and the post-Archean age of all the iron bearing formations of the Lake Superior country. But new evidence on the subject, secured principally during the past year, has been so decisive that he has not hesitated to announce as proven the existence of an Archean or Basement Complex iron-bearing formation.

If there is an Archean iron formation, to which the Michipicoten and Vermilion iron formations belong, then Dr. Coleman's argument as to the Upper Huronian age of conglomerates containing iron formation fragments is rendered ineffective, and the conclusions indicated by the structural evidence that the great conglomerates and accompanying rocks above described are Lower Huronian must stand, until decisive evidence to the contrary is found.

Grant[2] describes and maps the Upper and Lower Keweenawan copper-bearing rocks of Douglas county, Wisconsin. The Lower Keweenawan appears in a broad belt running from northeast to southwest across the county, widening toward the southwest, and in a small belt cutting through the southeastern corner of the county. It consists mainly of basic lava flows, associated with which, in the area in the southeast corner of the county, are a few beds of conglomerate composed of débris of the closely adjacent underlying rocks. The Upper Keweenawan appears in a broad belt in the southeastern part of the county between the two belts of Lower Keweenawan rocks. It is a series of conglomerates, sandstones and shales. In a belt north of the northern belt of Lower Keweenawan rocks, extending from these rocks to the shore of Lake Superior, is the Lake Superior sandstone (Cambrian). This is either flat-lying or dips slightly toward Lake Superior. The junction of the sandstone with the Lower Keweenawan is marked by a fault, along which the Lake Superior sandstone has been depressed, in some places probably as much as several hundred feet.

---

[1] The iron-ore deposits of the Lake Superior region, by C. R. VAN HISE: Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, 1901, p. 322.

[2] Preliminary Report on Copper Bearing Rocks in Douglas county, Wisconsin, by U. S. GRANT: Wisconsin Geological and Natural History Survey, Vol. VI, 1900, pp. 55.

The Upper and Lower Keweenawan belts form a syncline, the axis of which runs northeast and southwest through the center of the tract underlain by Upper Keweenawan rocks.

While the Keweenawan rocks of this area are the same in kind and age as are the productive copper-bearing rocks of Keweenaw Point, the probable unproductive character of the Douglas county rocks is intimated.

Alexander Winchell[1] prefaces a detailed petrographical description of certain phases of the gabbroid rocks of Minnesota with a brief account of the general succession in structure of formations in northeastern Minnesota. This is essentially the same as given by N. H. Winchell[2] in Volumes IV and V of the Minnesota State Survey. The correlation of this succession with the succession determined by the United States Geological Survey is discussed.

Comment.—Mr. Winchell's ideas as to succession and structure determined by the United States Geological Survey are naturally derived mainly from Bulletin 86 of the Survey and from the "Principles of Pre-Cambrian Geology" published in the Sixteenth Annual Report of the Survey. However, since these reports have been issued, the United States Geological Survey has done somewhat detailed field work in northeastern Minnesota as a result of which the ideas of the United States geologists on the succession and correlation have been considerably changed. The new conclusions of the Survey are briefly outlined by Van Hise in the Twenty-first Annual Report. This paper should be referred to by anyone reading Mr. Winchell's discussion of the correlation.

---

[1] Mineralogical and Petrographic study of the gabbroid rocks of Minnesota, and more particularly of the plagioclastites, by ALEXANDER N. WINCHELL: American Geologist, Volume XXVI, 1900, General part, pp. 153–162, with geological sketch map of Northeastern Minnesota.

[2] See summaries, JOUR. GEOL., Vol. IX, pp. 79–86.

Van Hise and Bayley[1] describe and map the geology of a portion of the Menominee iron district of Michigan.

The pre-Cambrian succession is as follows:

Algonkian	Upper Menominee	Hanbury slate. Vulcan formation, subdivided into the Curry ore-bearing member, Brier slate, and Traders ore-bearing member.
	Unconformity	
	Lower Menominee	Negaunee formation. Randville dolomite. Sturgeon quartzite.
	Unconformity	
Archean	- - - -	Granites and gneisses, cut by granite and diabase dikes. Quinnesec schists, cut by acid and basic dikes and veins.

In general the Algonkian rocks constitute a trough bounded on the north by the Archean rocks.

The Archean.— The Quinnesec schists are dark green or black basic schists and spheroidal greenstones, cut by large dikes of gabbro, diabase, and granite, and by smaller dikes of a schistose quartz porphyry. These occur in two areas, one along the Menominee River to the south of the Huronian rocks, and another in the west-central end of the district.

Bordering the Algonkian trough on the north is a complex of granites, gneisses, hornblende schists, and a few greenstone schists, all cut by dikes of diabase and granite. This complex is called the "Northern Complex." Most of the Archean rocks are igneous. Although there is no evidence of this, some of the fragmental tuffs may have been water-deposited. The Quinnesec schists and the Northern Complex are called Archean because they resemble lithologically other areas of Archean rocks in the Lake Superior country, and they both underlie the Algonkian series. The Northern Complex underlies the series with unconformity. The Quinnesec schists have not been observed in contact, and hence the presence or absence of a normal erosion unconformity cannot be inferred.

---

[1] The Menominee special folio, by CHARLES R. VAN HISE and S. W. BAYLEY: Geological Atlas of United States, Folio No. 62, U. S. Geol. Surv., 1900.

The Lower Menominee series. — The formations of the Lower Menominee series are observed only in the center and on the northern side of the Menominee trough. The Sturgeon formation is composed mainly of a hard white vitreous quartzite forming a continuous border of bare hills bordering the Archean complex. At its base is a coarse conglomerate made up of débris from the underlying Archean complex. The belt is in general a southward dipping monocline with dips varying from 25° to perpendicularity, although there are many reverse dips to the north. Its thickness is placed at from 1000 to 1250 feet.

Above, the Sturgeon quartzite grades into the Randville formation which is mainly a homogeneous dolomite interstratified with siliceous or argillaceous layers. This formation appears in three belts. The northern one is just south of the belt of the Sturgeon quartzite. The central belt is on the north side of Lake Antoine for a portion of its length, passes eastward between the Cuff and the Indiana mines, and ends at the bluff known as Iron Hill in the east half of Sec. 32, T. 40 N., R. 29 W. The southern belt of dolomite extends all the way from the western side of the sandstone bluff west of Iron Mountain to the village of Waucedah, at the eastern end of the mapped area. Structurally the northern belt of dolomite is a southward dipping monocline, while the two southern belts are anticlines. The thickness is not determined on satisfactory evidence, but is probably 1000 feet or more. The Randville formation is found, in a number of mines. in contact with the basal formation of the Upper Menominee series Here there is a coarse conglomerate in the basal part of the overlying formation indicating unconformity.

The Negaunee formation, overlying the Randville dolomite, is represented in the district by so few and so small outcrops that it is mapped with the Vulcan formation. Its presence is inferred mainly from the occurrence of abundant iron formation débris in the basal conglomerate of the Upper Menominee formation, showing that the Lower Menominee iron-bearing series must have been present. In the Marquette district an iron-bearing formation (the Negaunee) occupies an exactly similar stratigraphical position.

The Upper Menominee series.—The formations between the unconformity at the top of the Lower Menominee and the unconformity at the base of the Lake Superior sandstone, are placed in the Upper Menominee series. These occur in two great series, the Vulcan and the Hanbury.

The Vulcan formation is unconformable above the upper part of the Lower Huronian, which for most of the district is the Randville formation, and unconformable below the Hanbury slate. For parts of the district the Vulcan iron-bearing formation does not appear at all between the dolomite and the slate and its absence is explained by the unconformity between the Vulcan formation and the Hanbury slate. The Vulcan formation embraces three members. These are, from the base up, the Traders iron-bearing member, the Brier slate, and the Curry iron-bearing member. They are mapped as a single formation. The principal area of the Vulcan iron formation is in the belt 900 to 1300 feet wide, following the sinuosities of the southern border of the southern belt of Randville dolomite. It is generally absent north of the southern belt except at the east end where it appears at the Loretto mine and eastward. The second important area of Vulcan iron formation stretches off about five miles along the south side of the central dolomite belt running north of Lakes Antoine and Fumee, and ending somewhere about the east line of Range 30 West. At the east end of the dolomite area the iron-bearing formation appears in the lean slates at Iron Hill. The third stretch of country in which the iron-bearing beds are to be expected is that which borders the northern dolomite belt, but while pits have shown the existence of the formation here its distribution is unknown. The other areas in which the Vulcan formation may occur are those bordering the Quinnesec schists, but this has not yet been determined.

The Traders member consists of ferruginous conglomerate, ferruginous quartzite, heavily ferruginous quartzose slates and iron ore deposits. The Brier member consists of heavy black ferruginous and quartzose slates. The Curry member consists of interbedded japsilite, ferruginous quartzose slates and iron ore deposits. The relations of the Traders and Brier Hill members where there has been no disturbance of the strata is that of gradation. Where there has been disturbance, as in the vicinity of Norway, there has been a zone of differential movement between the two, resulting in slickensides and brecciated zones. Between the Brier slates and the Curry member there is gradation.

The Vulcan formation is bent into folds of several orders of

magnitude, the greater ones corresponding approximately to the folds in the underlying Randville dolomite. The total thickness of the formation is probably 600 to 700 feet.

The iron ore deposits of large size rest upon relatively impervious formations, which are in such positions as to constitute pitching troughs. A pitching trough may be made (*a*) by the dolomite formation underlying the Traders member of the Vulcan formations, (*b*) by a slate constituting the lower part of the Traders member, and (*c*) by the Brier slate between the Traders and Curry members of the Vulcan formation. The dolomite formation is especially likely to furnish an impervious basement where its upper horizon has been transformed into a talc-schist, as a consequence of folding and shearing between the formations.

Unconformably above the Vulcan iron formation is the Hanbury formation, which forms three large belts in the syncline of the older rocks, and occupies a very large proportion of the district. The formation comprises clay slates, calcareous slates, graphite slates, graywackes, quartzite, ferruginous dolomite, and rare bodies of ferruginous chert and iron oxide. The formation is much thicker than any of the other formations of the district, but it is probably not thicker than 2000 or 3000 feet.

Wilder[1] describes and maps the Sioux quartzites and quartz porphyries of Lyon county, Iowa. No points concerning the stratigraphy or age have been added to those already given by other writers.

Bain[2] describes the geology of the Wichita Mountains. Gabbros and porphyries of pre-Cambrian and probably of Archean age are present. The gabbro is more prominent in the western portion of the mountains, being especially well developed in the Raggedy Mountains, and the porphyry is more common in the eastern part of the mountains, being typically developed at Carrollton Mountain.

Matthews[3] gives a detailed petrographical description of the granites of the Pike's Peak quadrangle of Colorado. They are referred to the late Algonkian period.

---

[1] Geology of Lyon county, by FRANK A. WILDER: Iowa Geol. Surv., Vol. X, 1899, pp. 96–108.

[2] Geology of Wichita Mountains, by H. FOSTER BAIN: Bull. Geol. Soc. Am., Vol. XI, 1900, pp. 127–144, Pls. XV–XVII.

[3] The Granite Rocks of the Pike's Peak Quadrangle, by A. B. MATTHEWS: JOUR. GEOL., Vol. VIII, 1900, pp. 214–240.

Cross[1] maps and describes the geology of the Telluride quadrangle, Colorado, and briefly sketches the geology of the San Juan region, of which the Telluride quadrangle is a part.

In the Telluride quadrangle, along Canyon Creek north of Stony Mountain, is a small body of upturned quartzites, with an intercalated rhyolite sheet, which have been referred to the Algonkian. The quartzites are coarse and grade into fine conglomerate.

Ancient granites, gneisses, and schists are known in the Animas Valley and in the Uncompahgre plateau. These rocks have usually been considered as belonging to the Archean, but some of them are probably younger than the great series of quartzites exhibited in the Needle Mountains to the south, and younger than the quartzites beneath the volcanics in the canyons of the Uncompahgre, above Ouray, which have been referred to the Algonkian. These quartzites stand on edge or have been greatly disturbed. The relations of these isolated exposures to contemporaneous formations elsewhere are unknown.

Spurr[2] maps and briefly describes the Archean[3] granite of the Aspen district of Colorado. This is unconformably below and in direct contact with sediments of upper Cambrian age.

Davis[4] in a general account of a trip through the Colorado Canyon district briefly describes certain features of the pre-Cambrian geology. He calls attention to the extraordinary evenness of the floor of schists with granite dikes (Archean) upon which the Chuar and Unkar terranes (Algonkian) rest. The floor for the Paleozoic strata is somewhat less regular than the floor for the Unkar. In two places the pre-Cambrian rocks rise higher than the basal Tonto (Cambrian) sandstone. The Archean schists beneath the Unkar have a steep and regular slope, indicating uniform resistance to erosion. Where, beneath the Tonto, they show a bench, it is taken to indicate a softer character at this point, probably due to a longer period of pre-Tonto weathering.

---

[1] Telluride Folio, Colorado, by WHITMAN CROSS: Geol. Atlas of the U. S., No. 57, 1899.

[2] Geology of the Aspen Mining District, Colorado, with Atlas, by J. E. SPURR: Mon. U. S. Geol. Surv., No. 31, 1898, pp. 1–4.

[3] The term Archean is evidently used in the sense of pre-Cambrian.

[4] Notes on the Colorado Canyon District, by W. M. DAVIS: Am. Jour. Sci., 4th ser., Vol. X, 1900, pp. 251–259.

Blake[1] refers to the Archean the thick layers of gneiss forming the southern flank of the Santa Catalina Mountains, Arizona. The gneiss is in flat layers representing beds. A part of it is augen gneiss; other layers are quartzose and seemingly quartzites.

Knight[2] in connection with the discussion of the artesian basins of Wyoming gives a brief description, accompanied by a map, of the geology of the state. Algonkian and Archean rocks are present. The Archean rocks consist mainly of granite, in places cut by dikes of porphyry containing mineral ores, which can be seen in typical exposure at Sherman, Laramie Peak, east of Whalen Canyon, along the Big Horn, Wind River, Gros Ventre, Medicine Bow, Ferris, Seminoe, and Owl Creek ranges, along the Sweetwater River, a few miles northwest of Rawlins, and north of Clark's Fork, in Big Horn county.

The Algonkian rocks are for the first time separated from the Archean. They consist of schists in great profusion, marbles, and quartzites, all cut with dikes of eruptive rocks. They occur in granite basins in unconformity with the Archean, and form important bands in numerous localities. The strike of the series varies from north to northeast and the dip of the strata is seldom less than 65–75°. The thickness of the entire series has not been absolutely measured, but including the eruptive band, which does not form an important part, the maximum thickness in Wyoming is about 20,000 feet. Typical areas have been found in the Black Hills in Wyoming, and occasional outcrops from that place to the Hartville hills — one exposure being east of Lusk, another at Rawhide Butte, and a large one in Whalen Canyon. They also occur at Halleck Canyon, Plumbago Canyon, in the Medicine Bow Mountains, nearly all of the Sierra Madre Mountains, in the Seminoe Mountains and in the Sweetwater mining district of the Wind River range. None of these localities have been examined in detail; but sufficient work has been done to prove that these rocks were at one time sedimentary, and that they have been changed by metamorphism to schists. In the Sweetwater districts the rocks are chiefly schists; but there are many bands of erruptive rock that form dikes which follow the strike of the formation.

---

[1] Mining in Arizona, by WM. P. BLAKE: published in report of the Governor of Arizona to the Secretary of the Interior, Washington, 1899, p. 142.

[2] A preliminary Report on the Artesian Basins of Wyoming, by WILBUR C. KNIGHT: Wyoming Experiment Station, Bulletin No. 45, 1900. Part on pre-Cambrian, pp. 111–116. With geological map. This is the first geological map of Wyoming that has appeared.

Weed[1] maps and describes the pre-Cambrian rocks in the Fort Benton and Little Belt Mountains quadrangles of Montana.

The Archean rocks are found only in the Little Belt range in the southwestern part of the Fort Benton quadrangle and in the northwestern part of the Little Belt Mountains quadrangle. They are gneisses and schists of various kinds, and of somewhat uncertain origin. They are, in part at least, of igneous origin, and none of them show any traces of sedimentary origin. Their relations to the Algonkian rocks are those of unconformity. The Algonkian rocks are found in the mountain tracts of the Little Belt range, in Castle Mountain, and in the low range crossed by Sixteenmile Creek in the southwest corner of the Little Belt Mountain quadrangle. They are divided into the Neihart quartzite and the Belt formation,[2] both of which are parts of what Mr. Walcott has called the Belt Terrane.

The Neihart quartzite is a hard pink and gray quartzite forming the base of the Belt Terrane for this area. It is found in the vicinity of Neihart in the Little Belt Mountains. Its thickness is about six hundred feet. The Belt formation consists mainly of slaty, siliceous shales, but also contains interbedded limestone and quartzite. Fossils found in this series (in the shales above the formation which Mr. Walcott has named the Newland limestone member of the Belt Terrane), represent the earliest forms of life yet known. Near Neihart the Algonkian period is represented by 4000 feet of beds, while further south and west the thickness is much greater.

Overlying the Algonkian rocks conformably are rocks containing Middle Cambrian fossils. North of Neihart they rest directly on the Archean.

Reconnaissance geological surveys in Alaska and adjacent portions of British Columbia, by United States and Canadian government parties, have shown the basal rock over considerable areas to be a granite, which is provisionally assigned to the Archean.[3] Such granite is reported as occurring along the Pelly and Dease Rivers (Dawson[1] and Hayes;[2]) to the west, between the northern base of the St. Elias Mountains on the Yukon River (Hayes[3]); along the Upper Tanana River (Allen[4] and Brooks[5]), which is correlated by Spurr with the granite along the Pelly River; along Fortymile Creek, a tributary of the Yukon near the Canadian-Alaskan boundary (Spurr[6]); forming the core of the Kaiyuh Mountains (described by Dall,[7] referred to Archean by Spurr[8]); possibly forming the core of the Alaska Peninsula and the Aleutian Islands (noted by Dall[9] and Purington,[10] referred to Archean by Spurr[11]).

---

[1] Fort Benton and Little Belt Mountains Folios, by WALTER HARVEY WEED: Geol. Atlas of the U. S., Nos. 55 and 56, 1899.

See also Geology of the Little Belt Mountains, Montana: Twentieth Ann. Rept. U. S. Geol Surv., 1898–9, Pt. III, 1900, pp. 278–284.

[2] The Belt formation includes the various lithological members of the Belt Terrane which Mr. Walcott has named the Chamberlin shale, the Newland limestone, the Greyson shale, the Spokane shale, and the Empire shale.

[3] Usually in the sense of pre-Cambrian.

C. K. Leith.

On Rival Theories of Cosmogony. By the Rev. O. Fisher. *American Journal of Science*, June 1901, Pp. 414–422.

In this article the author has brought the current gaseo-molten hypothesis of the origin of the earth into comparison with the hypothesis of gradual accretion without a molten state recently advanced by Chamberlin, and has endeavored to test the tenability of the newer hypothesis by subjecting some of its fundamental postulates to mathematical and physical inquiries. The author disclaims holding a brief for either hypothesis and well sustains his claim to an impartial attitude.

---

[1] George M. Dawson: Geological Natural History Survey of Canada, Vol. III, Pt. I, 1887–8, p. 34B.

[2] C. Willard Hayes: Geographic Magazine, Vol. IV, 1892, p. 139.

[3] Loc. cit., p. 139.

[4] Lieutenant H. D. Allen: Expedition to the Copper, Tanana, and Koyukuk Rivers, Senate Documents, Washington, 1897, p. 159.

[5] A. H. Brooks: Twentieth Ann. Rept. U. S. Geol. Surv., Pt. VII, 1900, pp. 460–465.

[6] J. E. Spurr: Eighteenth Ann. Rept. U. S. Geol. Surv., Pt. III, 1898. pp. 134–140.

[7] W. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Surv., Pt. I, 1896, pp. 862, 863.

[8] J. E. Spurr: Twentieth Ann. Rept. U. S. Geol. Surv. Pt. VII, 1900, pp. 235 and 241.

[9] W. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Surv., Pt. I, 1896, p. 135.

[10] C. W. Purington: Manuscript map referred to by Spurr.

[11] J. E. Spurr: Twentieth Ann. Rept. U. S. Geol. Surv. Pt. VII, 1900, pp. 233–235.

He cites at the outset a difficulty, "perhaps more apparent than real," encountered by the newer hypothesis in the sporadic arrangement of the meteoric material which, if like known meteorites, would differ from the existing surface rocks. This difficulty, however, loses much, if not all, of its force when the effects of volcanic action are considered. The hypothesis assumes that the interior heat which arises from compression gives rise to the melting of certain constituents of the rock mass, and that these, previous to eruption, undergo magmatic differentiation into the well-known igneous rocks and probably into others which are but rarely ejected because of their high specific gravity, as the iron-bearing basalt of Disco Island, Greenland, and other extremely basic rocks of the ferro-magnesian type. Volcanic action is assumed to have begun effectively before the growing earth reached the size of the moon and all accretions subsequently made would be more or less invaded and overflown by igneous intrusions and extrusions of differentiated lava. In the closing stages of the earth's growth, the infall of meteoric matter declined gradually to an inappreciable amount, while the volcanic action is thought to have continued with relative vigor for a notable period after the essential cessation of growth, and to have perpetuated itself in less activity down to the present time. If the moon may be taken as an illustration of the prevalence and effectiveness of surface vulcanism in a body one eightieth of the earth's mass, it does not seem violent to suppose that the original meteoric matter of the earth would be deeply buried under surface lava flows and tuffs in the closing stages of its growth. Recent studies in the Lake Superior region, in Scandinavia, and in Lapland seem to concur in showing that the oldest known rocks consist of such lava flows and pyroclastic layers associated with some small amounts of ordinary clastic material, all mashed into schistosity. Into these schists, the great granitic series were intruded. Under the newer hypothesis these intrusions are to be regarded as merely a continuation of the earlier active vulcanism which was then more largely basic, but which had now, in the progress of magmatic differentiation, attained a dominant acidic character, perhaps as the partial complement of the earlier basic flows of the schist series or of the later basic flows of the Algonkian. The "fundamental gneiss" does not, therefore, appear, in the light of these recent studies, to be *fundamental*, nor does the "basement complex" appear to be *basal*. These recent investigations seem to bring the Archean series into almost ideal conformity with the accretion hypothesis, if under that hypothesis the process of accretion is conceived as dying away gradually by a transition into a stage of dominant vulcanism, which in turn gradually passes into the present phase of dominant aqueous activity. On the other hand, progressive investigation seems more than ever to give negative results in the line of the discovery of "the original crust" of the hypothetical molten stage, and the survival of the older hypothesis will perhaps require the recognition of a dominant eruptive stage similar to that postulated by the newer hypothesis, to which all or most of the Archean rocks are to be referred. In the light of these late Archean investigations, the difficulties of the old hypothesis seem at least as great as those of the new, for the old hypothesis must account for the non-appearance or scant appearance of "the original crust," while the new must account for the non-appearance or scant appearance of the supposed highly basic, magnesian, iron-bearing meteoric matter. The new hypothesis has the advantage of having theoretically postulated in advance what field studies are now bringing into recognition in spite of prepossessions inherited from the older view.

Passing the problem of superficial constitution as not necessarily serious, Fisher justly regards the increase of internal density and high internal temperature as incontestable facts of radical importance, and inquires how these facts may be accounted for on the meteoric theory. He assumes the average density of the meteoric matter to be nearly that of average surface rock, 2.75, and adds that "if this is too low, the arguments based upon it will not be affected in any great degree." Fisher feels tolerably certain that the law of internal density is fairly represented by Laplace's law, which is that "the increase of the square of the density varies as the increase of the pressure." In the case of a slow growth by solid accretion, the internal density must be mainly referred to compression. If, however, the specific gravity of the original meteoric material be taken at some figure between 3.5 and 4, as derived from known meteorites (Farrington's figure in 3.69), the amount of compression is appreciably less than on the assumption of 2.75 made in the computations. Fisher finds that at a depth of 400 miles, where by Laplace's law the density should be 3.88 the compressibility would be 1.4021×10^{-6}. "This may be looked upon as a small compressibility, seeing that the compressibility of water similarly measured is 4.78×10^{-5} or nearly forty times as great." The linear dimensions would be reduced about one tenth. "At the center the compressibility similarly measured would be very small, viz., 2.5×10^{-7}, while the condensation would be large, viz., 0.744."

In the absence of direct measurements on the compressibility of rocks, the author computes its value from the values of Young's modulus and the modulus of rigidity which have been obtained in some instances, and compares the result with the theoretical compressibility of surface rocks deduced from Laplace's law. Respecting the results, he remarks that "it is certainly not a little remarkable how closely this value ranges with those found by experiment. It is of the same order of magnitude but rather smaller than the average." He adds:

> We find here a somewhat strong presumption in favor of the view that the earth consists throughout of matter not very dissimilar from what we know at the surface, and that the internal densities are due rather to condensation than to the presence of heavier substances such as metals. But it is not a proof of this.

Respecting the alternative view that the greater density toward the center is due to heavy metals, Fisher says:

> We may probably dismiss the supposition that these all fell in first, and only regard them as segregated from a uniform mass of some kind, and having gravitated towards the center. This implies a condition of liquidity. If the materials were solid this separation could not have occurred. Now the only force that we know of that could cause the denser materials to move by a kind of convection towards the center is gravity; and in a solid gravity would not have that effect. Moreover, it must not be forgotten that gravity continually diminishes as we go deeper into the earth, and that at the center bodies have actually no weight. It is greatest at the surface, and if not competent to segregate downwards the heavy particles of a rock at the surface, which we know it is not, still less could it have that effect near the earth's center.
>
> Neither can we attribute this segregation to pressure; for pressures act equally upon the surface of heavy or light materials. If we had a layer of mixed shot and sand, no steady pressure laid upon it would force the shot to the bottom and bring the sand to the top.
>
> It seems, therefore, that the view that the denser materials in the interior consist of heavy metals necessitates a condition of liquidity of the whole, which accords more readily with the nebular than with the meteoric theory of its origin. For we may imagine that in a nebular mass cooling from the exterior, the first change from a nebulous or gaseous state would be the formation of a rain of condensed particles falling downwards, which would continue until the whole mass became liquid, and thus the heavier elements would begin to

collect towards the center. In this case the highest possible interior temperature would be that at which the gaseous first assumed the liquid condition under the pressure at the depth.

Paradoxical as it appears, it is therefore possible that the temperature in the interior may have been rendered higher by a conglomeration of cold solid meteorites than by the cooling of a nebula.

We have no means of judging whether the meteorites would come in rapidly or slowly, but in either case if we take no account of the heat arising from impact, the amount produced by condensation would be the same; the only difference in the two cases being that it would be generated in a less or greater time. In the meanwhile a covering of a badly conducting material would concurrently accumulate, preventing the rapid escape of this heat, and at the same time increasing the pressure, the compression, and the heat.

To form an idea of the temperature which would be produced by the condensation of matter of surface density to the density now existing at any given depth within the earth, not taking into account its diffusion by conduction or otherwise, we require to know the work which has been expended upon it. Now we can estimate this in the following manner. Conceive the earth to have been built up of meteorites falling in, so that shell after shell accumulated until the globe attained its present size. Then, fixing the attention upon a particular unit volume, say a cubic foot, of the substance, and omitting atmospheric pressure, it would successively be subject to every degree of pressure from zero, when the shell of which it formed a part was not covered up, until the present pressure was reached, when it was buried to the depth at which it now lies. If then we know the relation between the pressure and the compression at every depth at the present moment, it will give us the relation between the pressure and the compression which that particular volume has obeyed during the course of ages; that is to say, we can judge how much compression any given pressure would have produced in the substance under the conditions involved.

Laplace's law of density being based upon the assumption that the increase of pressure within the earth is proportional to the increase of the square of the density, in terms of a pressure of one pound upon the square foot, this leads to the result, that the pressure at the depth where the density is p is equal to $5.9 \times 10^7 (p^2 - s^2)$ [where s=density of surface rock and p= density of rock at the depth under consideration].

If we accept Laplace's law, this expresses a fact, whether the increase of density is due to condensation by pressure or to increased density in the intrinsic nature of the matter. But if we assume that the increase of density is caused solely by the pressure, then the above relation gives the amount of pressure which would reduce matter of density s to matter of density p under circumstances existing within the earth. It will therefore remain true if the matter changes its state from solid to liquid, and from liquid to gas. If, for instance, we wished to apply a pressure which would reduce surface rock to the density 3, it ought to be $5.9 \times 10^7 \ (9 - 2.75^2) = 8.481 \times 10^7$ pounds per square foot, supposing no heat be allowed to escape. If the experiment could be made, it would afford a test of the truth or otherwise of the present hypothesis.

When we know the relation between the pressure and the condensation which it would produce, it is feasible to estimate the heat which would be generated, and also the temperature, provided we assume the specific heat of the substance, which for surface rock has been determined. For instance, at the depth of 0.1 of the radius, or about 400 miles deep, where the density would be 3.88, the temperature produced by condensation would be 1.2608×10^5 Fahr., or 7.0044×10^4 Cent. [70,044°], while at the center the figures would reach 2.7756×10^6 Fahr., or 1.0242×10^6 Cent. [1,024,200°]. It seems at any rate that the meteoric theory would not fall short of accounting for temperatures as high as might be desired. It must at the same time be remembered that much of this heat would not be called into existence until the substance into which it was, as it were, being squeezed, had already been deeply buried under a badly conducting covering, so that the escape of heat would not take place as fast as it was generated, as would probably be the case with heat generated at the suface by impacts. Thus the hypothesis that the present high internal temperatures are due to compression seems quite admissible.

We may compare the above named temperatures with some that are known. Acheson, for instance, obtains 6500° Fahr. in his Carborundum electric furnace, and 3300° Fahr. has been obtained by the oxyhydrogen flame. These temperatures are contemptible compared with those mentioned above. The Hon. Clarence King, prolonging Dr. Barus' line for the melting point of diabase (which is 1170° C. at the earth's surface) to the earth's center, gives the temperature 76000° Cent., which is of the same order of magnitude as condensation would produce at only 400 miles depth.

Fisher considers the bearing of the temperature of lava as determined by Bartoli at Etna (1060°C. or 1932° F.) on the question, and finds that the theoretical depth at which this lava temperature would be produced by condensation would be about forty-three miles. The same temperature would be reached at the accepted gradient of 1° F. for sixty feet in about twenty-two miles.

It seems then that the hypothesis, that the internal densities are due to the condensation of matter of surface density, will not account for a temperature gradient originally as high as at present. [The computed gradient corresponds pretty nearly with the low gradient found at the Calumet and Hecla

magnitude, the greater ones corresponding approximately to the folds in the underlying Randville dolomite. The total thickness of the formation is probably 600 to 700 feet.

The iron ore deposits of large size rest upon relatively impervious formations, which are in such positions as to constitute pitching troughs. A pitching trough may be made (*a*) by the dolomite formation underlying the Traders member of the Vulcan formations, (*b*) by a slate constituting the lower part of the Traders member, and (*c*) by the Brier slate between the Traders and Curry members of the Vulcan formation. The dolomite formation is especially likely to furnish an impervious basement where its upper horizon has been transformed into a talc-schist, as a consequence of folding and shearing between the formations.

Unconformably above the Vulcan iron formation is the Hanbury formation, which forms three large belts in the syncline of the older rocks, and occupies a very large proportion of the district. The formation comprises clay slates, calcareous slates, graphite slates, graywackes, quartzite, ferruginous dolomite, and rare bodies of ferruginous chert and iron oxide. The formation is much thicker than any of the other formations of the district, but it is probably not thicker than 2000 or 3000 feet.

Wilder[1] describes and maps the Sioux quartzites and quartz porphyries of Lyon county, Iowa. No points concerning the stratigraphy or age have been added to those already given by other writers.

Bain[2] describes the geology of the Wichita Mountains. Gabbros and porphyries of pre-Cambrian and probably of Archean age are present. The gabbro is more prominent in the western portion of the mountains, being especially well developed in the Raggedy Mountains, and the porphyry is more common in the eastern part of the mountains, being typically developed at Carrollton Mountain.

Matthews[3] gives a detailed petrographical description of the granites of the Pike's Peak quadrangle of Colorado. They are referred to the late Algonkian period.

---

[1] Geology of Lyon county, by FRANK A. WILDER: Iowa Geol. Surv., Vol. X, 1899, pp. 96–108.

[2] Geology of Wichita Mountains, by H. FOSTER BAIN: Bull. Geol. Soc. Am., Vol. XI, 1900, pp. 127–144, Pls. XV–XVII.

[3] The Granite Rocks of the Pike's Peak Quadrangle, by A. B. MATTHEWS: JOUR. GEOL., Vol. VIII, 1900, pp. 214–240.

Cross[1] maps and describes the geology of the Telluride quadrangle, Colorado, and briefly sketches the geology of the San Juan region, of which the Telluride quadrangle is a part.

In the Telluride quadrangle, along Canyon Creek north of Stony Mountain, is a small body of upturned quartzites, with an intercalated rhyolite sheet, which have been referred to the Algonkian. The quartzites are coarse and grade into fine conglomerate.

Ancient granites, gneisses, and schists are known in the Animas Valley and in the Uncompahgre plateau. These rocks have usually been considered as belonging to the Archean, but some of them are probably younger than the great series of quartzites exhibited in the Needle Mountains to the south, and younger than the quartzites beneath the volcanics in the canyons of the Uncompahgre, above Ouray, which have been referred to the Algonkian. These quartzites stand on edge or have been greatly disturbed. The relations of these isolated exposures to contemporaneous formations elsewhere are unknown.

Spurr[2] maps and briefly describes the Archean[3] granite of the Aspen district of Colorado. This is unconformably below and in direct contact with sediments of upper Cambrian age.

Davis[4] in a general account of a trip through the Colorado Canyon district briefly describes certain features of the pre-Cambrian geology. He calls attention to the extraordinary evenness of the floor of schists with granite dikes (Archean) upon which the Chuar and Unkar terranes (Algonkian) rest. The floor for the Paleozoic strata is somewhat less regular than the floor for the Unkar. In two places the pre-Cambrian rocks rise higher than the basal Tonto (Cambrian) sandstone. The Archean schists beneath the Unkar have a steep and regular slope, indicating uniform resistance to erosion. Where, beneath the Tonto, they show a bench, it is taken to indicate a softer character at this point, probably due to a longer period of pre-Tonto weathering.

---

[1] Telluride Folio, Colorado, by WHITMAN CROSS: Geol. Atlas of the U. S., No. 57, 1899.

[2] Geology of the Aspen Mining District, Colorado, with Atlas, by J. E. SPURR: Mon. U. S. Geol. Surv., No. 31, 1898, pp. 1–4.

[3] The term Archean is evidently used in the sense of pre-Cambrian.

[4] Notes on the Colorado Canyon District, by W. M. DAVIS: Am. Jour. Sci., 4th ser., Vol. X, 1900, pp. 251–259.

the effects of snow banks. The thickness of the névé fields which did not become glaciers is estimated to have been 100 to 150 feet, and the conclusion is reached that, on a grade of about 12 per cent., the névé must attain the thickness of at least 125 feet in order to have motion.

Certain phases of the problem of glacial motion are touched, and the conclusion reached that the cause of glacial motion is to be sought in the weight of the ice mass, and that it is independent of the temperature of the air. No attempt is made, however, to decide the real nature of glacial motion, or what processes are involved in it.

R. D. S.

Annual Report of the Board of Regents of the Smithsonian Institution, showing the Operations, Expenditures, and Condition of the Institution for the year ending June 30, 1899.

In the appendix accompanying the official report of the governing bodies and the secretary of the Smithsonian Institution, a complementary number of geological articles are introduced. These are, for the most part, republications, and include "On Lord Kelvin's Address on the Age of the Earth as an Abode Fitted for Life," by T. C. Chamberlin; "An Estimate of the Geological Age of the Earth," by J. Joly; "The Petrified Forests of Arizona," by Lester F. Ward; "Present Conditions of the Floor of the Ocean; Evolution of the Continental and Oceanic Areas," by Sir John Murray; "The Truth About the Mammoth," by Frederic A. Lucas; "Mammoth Ivory," by R. Lydekker; and "Review of the Evidence Relating to Auriferous Gravel Man in California," by William H. Holmes. Several of the physical and biological articles, and those relating to general aspects of science, also possess points of interest to geologists.

C.

Recent Publications

—**Becker, George F.** Conditions Requisite to our Success in the Philippine Islands. An address delivered before the American Geographical Society, February 20, 1901. [Reprinted from Bull. of the Am. Geog. Soc., April 1901.]

Report on the Geology of the Philippine Islands. Followed by a version of Ueber Tertiäre Fossilien von den Philippinen (1895) by K Martin. [Extract from the Twenty-first Annual Report of the U. S. Geological Survey, 1899–1900. Part III—General Geology, Ore and Phosphate Deposits, Philippines.] Washington, 1901.

—**Collie, George Lucius.** Wisconsin Shore of Lake Superior. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 197–216.] Rochester, April 1901.

—**Davis, W. M.** An Excursion in Bosnia, Hercegovina, and Dalmatia. [From Bulletin, Vol. III, No. 2, Geog. Soc. of Philadelphia.]

An Excursion to the Grand Canyon of the Colorado. [Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXVIII. Geological Series, Vol. V, No. 4; with two plates.] Cambridge, Mass., May 1901.

The Geographical Cycle. [Paper read at the Seventh International Geographical Congress of Berlin in 1899.] Berlin, 1900.

—**Dorsey, George A.** Archæological Investigations on the Island of La Plata, Ecuador. [Field Columbian Museum, Publication 56; Anthropological Series, Vol. II, No. 5.] Chicago, April 1901.

—**Dorsey, George A and H. R. Voth.** The Oraibi Soyal Ceremony; The Stanley McCormick Hopi Expedition. [Field Columbian Museum, Publication 55; Anthropological Series, Vol. III, No. 1.] Chicago, March 1901.

—**Dumble, E. T.** I, Cretaceous of Obispo Canyon, Sonora, Mexico. [Reprinted from the Transactions of the Texas Academy of Sciences, Vol. IV, Part I, 1900.] II, Occurrence of Oyster Shells in Volcanic Deposits in Sonora, Mexico.

Geology of the Beaumont Oil Field.

Natural Coke of the Santa Clara Coal-Field, Sonora, Mexico. [Transactions of the American Institute of Mining Engineers, California Meeting, September 1899.]

The Iron Ores of East Texas.

The Oil Deposits of Texas.

—ELLIOT, D. G. A List of the Land and Sea Mammals of North America North of Mexico. [Field Columbian Museum, Publication 57; Zoölogical Series, Vol. II, No. 2.] Chicago, June 1901.

A List of Mammals obtained by Thaddeus Surber, in North and South Carolina, Georgia, and Florida. [Field Columbian Museum, Publication 58; Zoölogical Series, Vol. III, No. 4.] Chicago, June 1901.

The Caribou of the Kenai Peninsula, Alaska. [Field Columbian Museum, Publication 59; Zoölogical Series, Vol. III, No. 5.] Chicago, July 1901.

—FISHER, REV. O. On Rival Theories of Cosmogony. [From the American Journal of Science, Vol. XI, June 1901.]

—India, Geological Survey of. General Report for the Year ending March 31, 1901. C. L. Griesbach, Director. Calcutta, 1901.

—New Jersey, Geological Survey of. Annual Report of the State Geologist for the Year 1900. Trenton, N. J., 1901.

—NUTTING, C. C. The Hydroids of the Woods Hole Region. [Extracted from U. S. Fish Commission Bulletin for 1899, pp. 325–386. Date of publication, June 8, 1901.] Washington, 1901.

—OLDHAM, R. D. Beach Formation in the Thirlmere Reservoir. [Abstract of a paper read before the British Association, Bradford, 1900.]

—Øyen, P. A. Variations of Norwegian Glaciers. [Separataftryk af "Nyt f. Naturvidenskab," B. 39, H. 1. Kr. ania, 1901.] Christiania, April 1901.

—RABOT, CHARLES. Les Variations des Longueur Des Glaciers dans les Régions Artiques et Boréales. [Extrait des Archives des sciences physiques et naturelles Années 1899 et 1900.] Genéve et Bale, 1900.

—REID, H. F. Observations of Earthquakes. [From the Johns Hopkins University Circular, No. 152, May 1901.]

The Variations of Glaciers, VI. [Reprinted from the JOURNAL OF GEOLOGY, Vol. IX, No. 3, April–May 1901.]

—SHALER, N. S. Broad Valleys of the Cordilleras. [Bulletin of the Geol. Soc. of Am., Vol. XII, pp. 271–300.] Rochester, June 1901.

—SHIMEK, B. The Loess of Iowa City and Vicinity. Iowa Pteridophyta (Con.). Addenda to the Flora of Lyon County. [Excerpt from the Bulletin of the Laboratories of Natural History, State University of Iowa, Vol. V, No. 2, pp. 195-216.] May 1901.

The Iron Ores of East Texas.

The Oil Deposits of Texas.

—ELLIOT, D. G. A List of the Land and Sea Mammals of North America North of Mexico. [Field Columbian Museum, Publication 57; Zoölogical Series, Vol. II, No. 2.] Chicago, June 1901.

A List of Mammals obtained by Thaddeus Surber, in North and South Carolina, Georgia, and Florida. [Field Columbian Museum, Publication 58; Zoölogical Series, Vol. III, No. 4.] Chicago, June 1901.

The Caribou of the Kenai Peninsula, Alaska. [Field Columbian Museum, Publication 59; Zoölogical Series, Vol. III, No. 5.] Chicago, July 1901.

—FISHER, REV. O. On Rival Theories of Cosmogony. [From the American Journal of Science, Vol. XI, June 1901.]

—India, Geological Survey of. General Report for the Year ending March 31, 1901. C. L. Griesbach, Director. Calcutta, 1901.

—New Jersey, Geological Survey of. Annual Report of the State Geologist for the Year 1900. Trenton, N. J., 1901.

—NUTTING, C. C. The Hydroids of the Woods Hole Region. [Extracted from U. S. Fish Commission Bulletin for 1899, pp. 325–386. Date of publication, June 8, 1901.] Washington, 1901.

—OLDHAM, R. D. Beach Formation in the Thirlmere Reservoir. [Abstract of a paper read before the British Association, Bradford, 1900.]

—Øyen, P. A. Variations of Norwegian Glaciers. [Separataftryk af "Nyt f. Naturvidenskab," B. 39, H. 1. Kr. ania, 1901.] Christiania, April 1901.

—RABOT, CHARLES. Les Variations des Longueur Des Glaciers dans les Régions Artiques et Boréales. [Extrait des Archives des sciences physiques et naturelles Années 1899 et 1900.] Genéve et Bale, 1900.

—REID, H. F. Observations of Earthquakes. [From the Johns Hopkins University Circular, No. 152, May 1901.]

The Variations of Glaciers, VI. [Reprinted from the JOURNAL OF GEOLOGY, Vol. IX, No. 3, April–May 1901.]

—SHALER, N. S. Broad Valleys of the Cordilleras. [Bulletin of the Geol. Soc. of Am., Vol. XII, pp. 271–300.] Rochester, June 1901.

—SHIMEK, B. The Loess of Iowa City and Vicinity. Iowa Pteridophyta (Con.). Addenda to the Flora of Lyon County. [Excerpt from the Bulletin of the Laboratories of Natural History, State University of Iowa, Vol. V, No. 2, pp. 195-216.] May 1901.

THE

JOURNAL OF GEOLOGY

SEPTEMBER-OCTOBER, 1901

THE RIVER SYSTEM OF CONNECTICUT[1]

THE tendency of the modern school of physiographers seems to be to ascribe little importance to geological structure planes as a factor in determining the position and the orientation of water courses. In an earlier period greater attention seems to have been accorded to this condition, and quite apart from the purely theoretical conceptions of the closet geologists many valuable observations were placed upon record. Th. Kjerulf, the former Director of the Geological Survey of Norway, remarked the regularity in the arrangement of fjords, streams, and valleys as represented upon the map of Norway, and from this was led to believe that their directions corresponded to the faults in a system of dislocations. Daubrée[2] has furnished many examples of regular networks of stream channels which resemble the network produced by a number of intersecting series of parallel joint planes (*réseaux réguliers de cassures*), and the explanation of this correspondence he believed to be a causal one, the planes of separation, or jointing, being locally gaping where the streams adhere to the joint direction, but closed where they have been diverted from the course of the joint. Van Hise[3] has in a similiar way explained the zigzags of the small streams which enter the Wisconsin River at the "Dells" as due to a system of joints induced by the gentle folding of the rocks. That a more or less uniform system of joints exists in the rocks almost throughout the state of Wisconsin has been shown by Buckley's observations.[1]

---

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] DAUBRÉE: Géologie Experimentale. Paris, 1879, p. 361.

[3] VAN HISE: Trans. Wis. Acad. Sci., etc., Vol. X., pp. 556-560, 1895.

So far as the writer is aware, the only detailed studies that have been made establishing the definite relationship of the stream channels of a region to its system of joints or faults, are those of Brögger[2] in the Langesund-Skien and Christiania regions of southern Norway, and that of the writer[3] in the Pomperaug Valley region of Connecticut. Of the elaborately faulted region which Brögger has studied, he states:

> It is not exaggerated when to my own astonishment I must state, as the final result of my observations in this region, that almost every valley, every cleft, is formed along a fault fissure. . . . . The significance of the faults for the formation of the valley straits is thus as profound as possible within the stretch of land described, since almost every cliff, every vale, every bay has been formed upon a line of dislocation; indeed the presence of clefts was for me, at the last, the surest index for the discovery of dislocations.[4] [Translation.]

Review of the geological structure of the Pomperaug Valley area of Connecticut.—Regarding the Connecticut area to which reference is made, it will be necessary here to review the study in order to make clear the generalizations with which this paper is especially concerned. It is now well known that the several areas of Newark rocks of the eastern United States are complexly faulted, and the many common structural peculiarities of the several isolated areas give rise to the belief that the forces which have produced the dislocations have affected, not the Newark rocks alone, but the larger region of which they are parts—the Piedmont plateau of the eastern United States.[5]

---

[1] BUCKLEY: Bull. 4, Geol and Nat. Hist. Surv. Wis., pp. 450–460, 1898.

[2] BRÖGGER: Nyt Magazin for Naturvidenskaberne, Vol. XXVIII, pp. 253–419, 1884. *Ibid.*, Vol. XXX, pp. 99–231, 1886.

[3] HOBBS: Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, 1901, pp. 1–162.

[4] Op. cit., pp. 34, 342.

[5] Cf. DAVIS: The Triassic Formation of Connecticut, Seventh Ann. Rept. U. S. Geol. Surv., 1888, pp. 481–490.

The detailed study of the Pomperaug Valley area has developed the fact that a complex system made up of intersecting series of parallel nearly vertical joints and faults there divides the crust into a large number of orographic blocks, the smaller of which have dimensions of less than one hundred paces. The different throws along the numerous faults bounding these blocks have brought about a structure not unlike that of a mosaic from which the supporting base has been lowered and the individual stones been displaced by different amounts due to the inequalities of their lateral support. For the area as a whole, the joints and corresponding faults are embraced mainly in four series, the individual members in which trend N. ± 34° W., N. ± 55° E., N. ± 5° W., and N. ± 15 E. Series of faults less common for the area as a whole, but several of them numerous enough in its southern portions, have directions N. ± 33° E., N. ± 44° W., N. ± 61° W., N. ± 90° E. W., N. ± 20° E., and N. ± 25° W., the order being approximately that of frequency of occurrence. Of the more common series, those trending N. ± 55° E. and N. ± 34° W. are nearly normal to one another, as would be true of a pair of joint planes, but the larger throws within the region seem generally to have taken place along one of these planes (N. ± 55° E.) and one of the other prevailing directions (N. ± 5° W.). Aside from the regularity in direction observed to characterize the numerous faults and bring them into a number of parallel series, those faults of the same order of displacement are observed to be spaced also with noteworthy regularity. The smallest of the orographic blocks which could be measured, for convenience called the "unit" blocks, were found to be quite generally about 50 paces (150 feet) along the direction N. ± 55°E., and 100 paces (300 feet) along the direction N. ± 5° W.—the equivalent of two rhombic prisms in contact along one side. The larger, or "composite" blocks, which are of various orders of magnitude, are made up of the "unit" blocks and bordered by displacements of a higher order—greater throw. The fault intervals in the several series, and hence the shapes of the orographic blocks, are found to be closely related to the directions of the prevailing and rarer fault series in a manner which is made clear by the diagram of Fig. 1. In this figure the shape of the unit orographic block—and of many composite blocks of several orders as well—is shown by the black and also by the stippled area. Two of the prevailing fault directions, N. ± 15° E. and N. ± 34° W. correspond to the longer and the shorter diagonals respectively of this unit block. The fault direction N. ± 33° E., which is the most common of those occurring in the southern Pomperaug area, corresponds closely to the longer diagonal of three unit blocks in contact along their longer side. Another of the series of faults characteristic of the same southern area and trending N. ± 20° E., corresponds to the longer diagonal of six unit blocks, two composite blocks like those just described placed in contact along their longer sides. The remaining directions of faults observed in the area are respectively the shorter diagonals of composite blocks three units long and two wide, four long and six wide, four long and seven wide, and two long and seven wide; though clearly in these latter instances, the relationships indicated in the diagram are less significant owing to the more complex nature of the composite blocks of which the fault directions are the diagonals. For a more important indication of the same relationship, which is observed in the actual composite blocks of the area studied, the reader must be referred to the original report.[1]

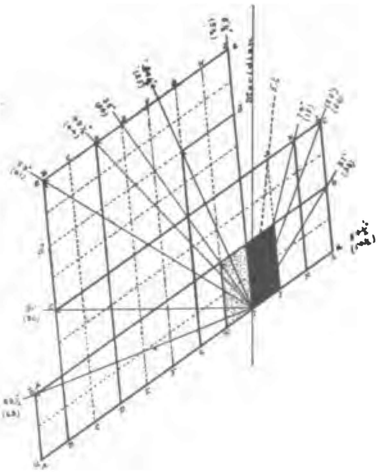


FIG. 1.—Diagram to illustrate the relationships existing between the shape of the "unit" orographic blocks and the directions of the fault series.

For the area in question the conclusion has been drawn that the earth's crust has been here subjected to compressive stresses, the resultant of which acted in a direction normal to the axis of Green Mountain folding (N. ± 80° W.), stresses which were relieved by dislocation along the planes of maximum shear, approximately 45° to either side of the direction of pressure, *i. e.*, S. ± 55° W. (N. ± 55° E.) and N. ± 34° W. The remaining common directions of fault planes (N. ± 15° E. and N. ± 5° W.) could be explained by a subsequent development of compressive stress acting along the initial direction; for in a region containing planes of separation at 45° to the direction of pressure, there would be a resolution of the stress into components acting along the planes of separation and along that diagonal of the blocks which is nearly normal to the pressure. The direction N. ± 15° E. corresponds to this diagonal of the joint block already formed, and the remaining direction N. ± 5° W. is the corresponding diagonal of two such blocks in contact. To explain these latter dislocations upon the same principle, it must be assumed that, owing to differences between the alternate joint planes of the same series, these double joint blocks acted to some extent as units. The fault directions characteristic especially of the southern portion of the area and disclosing such intimate relationships to the four generally prevalent ones, might be explained either by assuming that in the later compression of the jointed area composite blocks of different shapes, because composed of a different number or different arrangement of unit blocks, acted as units (whether due to the greater perfection of their bounding fault planes over intermediate ones, to the partial closing or healing of the intermediate faults, or to some other cause). In this case the maximum shear would be along the diagonal of the composite blocks, as would be the case in the unit blocks themselves, and it is shown in the report under review that these directions do correspond, *not only in direction, but also in position* with the diagonals of important composite blocks of the area. Under certain conditions, which may or may not have obtained in the area, planes of dislocation having the same directions might have been produced through the depression of the composite blocks subsequent to the jointing of the area, since in this case also the tendency would be for blocks to rupture along the diagonals.

---

[1] Loc. cit. pp. 117–120.

The oriented drainage of the Pomperaug Valley.—With this brief summary of the geological structure within the Pomperaug Valley area we may consider its drainage. It was found in studying the area that the streams, large and small, for considerable distances adhere with great fidelity to the directions of some of the prevailing faults, and that in many cases after being diverted from them, it was noted that they had returned persistently to the old direction. This correspondence of drainage lines to geological structure planes is far too close to be accidental. The four prevailing fault series diverge from their nearest neighbors at angles of about 39°, 20°, 29°, and 92°. A difference in angle between a fault direction and the general direction of a stream course equivalent to 7°, or about one third the smallest difference of angle between neighboring fault directions, would represent a divergence of one in eight, which would hardly be accepted by the eye as an indication of parallelism. It is not to be expected that the actual course of a stream will now be coincident with or even absolutely parallel to any fault direction, for there have unquestionably been many local conditions which have produced larger or smaller migrations of the river channels. Their general direction has, however, it would seem, been maintained despite the minor accidents which have marked their life-histories, and even under so revolutionary a change as complete reversal of drainage.

It was further shown in the investigation under review, that in the walls of crystalline rocks surrounding the Newark beds in the Pomperaug basin, the same adhesion of the water courses to the direction of the observed faults (extended) could be determined. It was hardly to be expected that these peculiarities would cease to be observable so soon as the immediate vicinity of the Newark basin was left behind, if it be indeed true that the dislocation of the area is due to a compression of the general region in which this area of Newark rocks and the much larger one of the Connecticut valley are included. Owing, however, to the absence over the greater part of the surrounding area of widely different rocks in thin beds, the difficulties of locating fault planes are almost infinitely increased; and, indeed, except under especially fortuitous conditions they elude observation. Having established, however, a relationship in one area, the problem is before us to determine whether the river system of the larger area of Connecticut exhibits any indication of the existence of rectilinear directions more or less persistent embraced in a network of parallel series like that of the Pomperaug Valley; or, if this be not true, whether any other persistent and recurrent directions can be observed. It will be further of special interest if such a system affords indication of a regular space-interval between such parallel lines of drainage.

The oriented drainage of the Shepaug River.— In prosecuting our inquiry regarding the orientation of the drainage lines of Connecticut, the valley of the Shepaug River (its southern portion) was first examined, since this basin immediately adjoins to the west that of the Pomperaug. The diagram of this river traced from the atlas sheet of the map of Connecticut, prepared by the topographic corps of the United States Geological Survey (Fig. 2), affords clear evidence that the geological structure planes have here played an important part in giving direction to the river's channels. The dotted lines of the figure show the inferred approximate positions of fault planes whose course the river has adopted. The most marked adhesion of the river or its

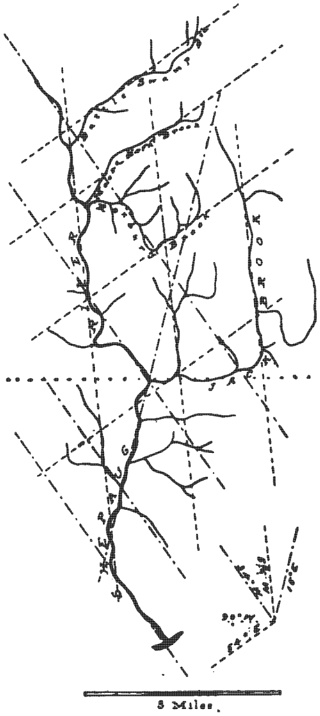
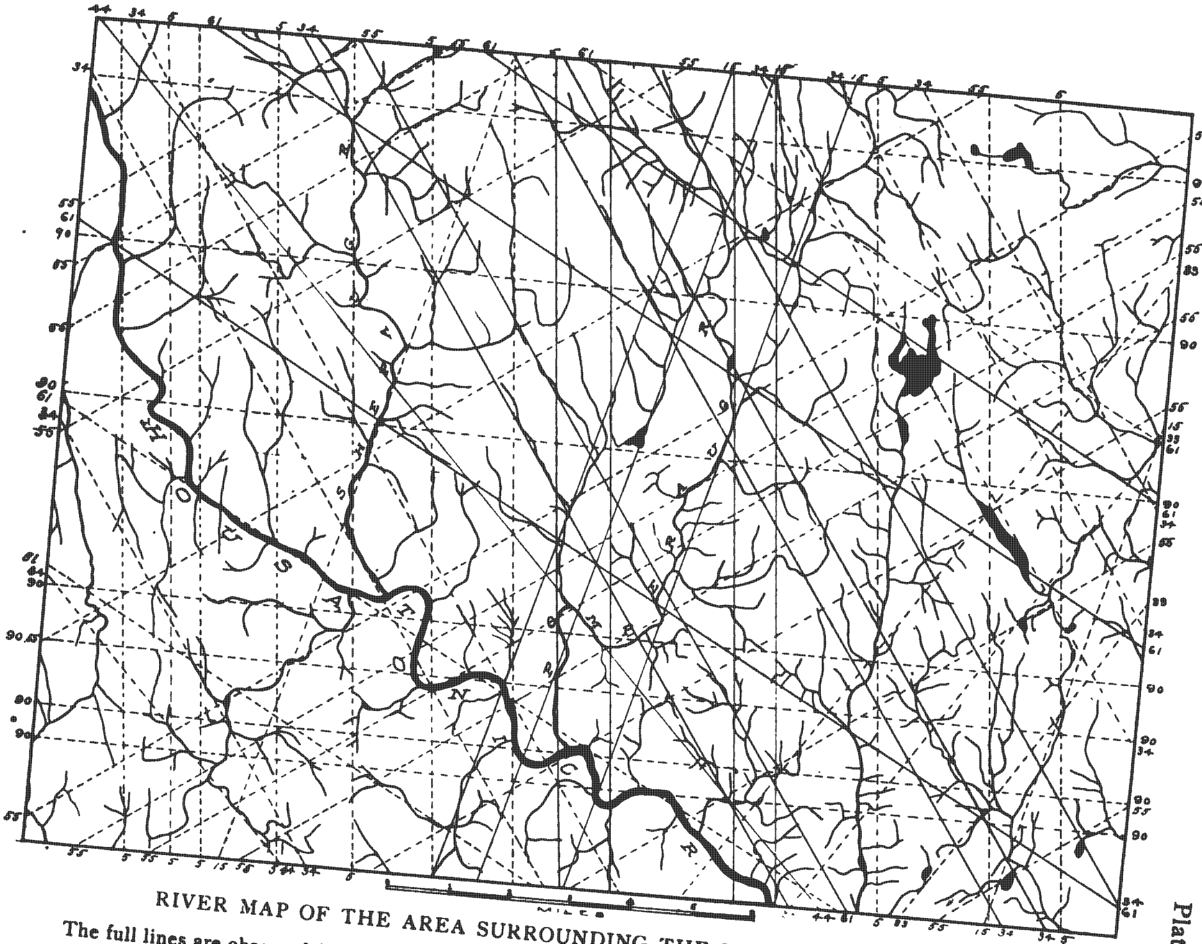


FIG. 2.— Diagram to show the relationship of drainage lines in the basin of the Shepaug River to the prevalent fault and joint lines of the neighboring Pomperaug basin.

branches to any given direction is very closely the direction N. 5° W., as shown by the upper course (in the diagram) of the trunk stream, as well as by the upper course of Jack Brook, its main eastern tributary, and by the small intermediate branch of the latter. These three channels are not only evenly spaced, but to the southward their extensions correspond in position with the southerly trending elements of great elbows of the Housatonic (see Plate II). After receiving the waters of Jack Brook, the Shepaug flows for nearly three miles in the direction S. ± 15° W. (N. ± 15° E.), another of the four prevailing fault directions observed in the Pomperaug Valley. Later it flows S. ± 34° E. (N. ± 34° W), while several tributaries flow along this direction and S. ± 55° W. (N. ± 55° E.), the two remaining of the four prevalent fault directions of the Pomperaug Valley.

The oriented drainage within the area surrounding the Pomperaug Valley.— In the map of Plate II, a larger area, of which the Pomperaug Valley is the center, has been considered. Upon this map, traced from the United States Geological Survey atlas sheets, which are on a scale of one inch to the mile, the full straight lines represent observed faults (extended), and the dotted lines the inferred approximate position of faults. It has, of course, been necessary to omit all but a few of the numerous faults which were observed in the Pomperaug Valley area. The figures on the margin of the map indicate the directions (in degrees) either to the east or west of north of the trough or fault lines which emerge near them. With the greater complexity of this map and the larger number of fault directions represented, relationships are not at once so apparent as in Fig. 2, which upon a reduced scale is here included. Special attention is directed, however, to the fact that the Housatonic itself, which after flowing about three miles in a direction S. ± 5° E. (N. ± 5° W.), assumes the direction S. ± 61° E. (N. ± 61° W.) at first in a nearly straight channel for three miles, and then in a zigzag course for eight miles more. Many interesting peculiarities will be noticed in the orientation of the smaller streams shown upon this map; as, for example, along the N. ± 55° E.

Plate II



RIVER MAP OF THE AREA SURROUNDING THE POMPERAUG VALLEY

The full lines are observed faults of the Pomperaug Valley area (extended); the dotted lines are "trough lines" (inferred approximate positions of joint or fault planes); the figures on the margin give the angle in degrees to the east or west of the meridian of the "trough lines" which pass near them.

line which approximates to a diagonal of the map, along the N. ± 33° E. line which meets the lower margin of the map near where the Housatonic meets it, etc. It will hardly escape notice, also, that the most marked lines in each series are spaced with considerable regularity, and if one space is wider than the others, it is often so much wider as to suggest that the space-interval is a multiple of the space which has been regarded temporarily as the unit.

The river system of Connecticut.—An examination of the larger area approximately coëxtensive with that of the state of Connecticut has been made by use of the "two-sheet map of Connecticut," on a scale of one half inch to the mile, prepared by the United States Geological Survey Those lines and characters of this map, such as topography and culture, with which we are not now concerned and which would obscure the relationships sought, were eliminated by preparing a careful tracing of all the streams and their minor branches. Upon this map tracing (about six feet long by four wide) approximately rectilinear stretches of river channel, and especially the stretches of neighboring streams which hold approximately to the same line, were sought. If these directions were found to agree closely with any of the fault directions observed in the Pomperaug basin, dotted lines were drawn following those directions and coinciding as closely as possible with the river courses. If such an observed direction was found not to coincide closely with any of the fault directions determined, a direction was sought which would approximate most closely to it, and a similar dotted line with this direction drawn along the course of the river. The term "trough lines" used to designate these lines, need for the present be given no further signification than lines so favored by nature that the waters of the region have been induced to adopt them for their channels over longer or shorter distances. On a map of this scale the trough lines, if rectilinear, should be slightly curved, but inasmuch as the present river courses, because of the many accidents of their history, can only roughly approximate to the direction initially given them, it would be an over-refinement to introduce a correction of this nature, and they are, therefore, left straight. When all important trough lines had been thus represented, the map was reduced by photography and the etching of Plate I produced after the important rivers had been made a little heavier in order that their course might be apparent. These details of the study have been noted because the dangers of introducing the personal element while drawing the course of a river with any theory of its orientation in mind are very great. The map conveys a wrong impression, therefore, chiefly in its slightly exaggerating the volume of certain streams which it was necessary to draw with heavier lines in order that their correspondences might be apparent.

The first trough lines to impress the observer are those designated a_1, a_2, a_3, a_4, upon the map, lines which trend approximately N. 44° W., and which include the lower reaches of the Housatonic, of the Connecticut below Middletown, of the lower Willimantic and the Shetucket, and a stretch of the Quinebaug. A less-marked trough line between a_1 and a_2, would include important bends of the Naugatuck and Quinnipiac rivers. The sharp bend of the Connecticut River at Springfield and Patchoug River, tributary to the Quinebaug, may indicate the course of another trough line in this series. Most noteworthy of all lines in this series, however, is a_2, since the lower stretch of the Connecticut (some twenty-five miles long) is continued in the zigzag Sebethe River, so as almost to connect with the stretch of the Farmington River above its sharpest bend at Farmington. The direction of the lower stretch of the Connecticut is of especial interest because the river at Middletown deserts the softer Newark sediments to flow across the crystalline uplands, a peculiarity which has been explained by Professor Davis[1] through conformable superimposition, the stream being supposed powerful enough to maintain an initial course along this direction during the rise of the uplands, at which time the harder gneisses were discovered. The same hypothesis has been offered by Kümmel[2] to explain the lower course of the Housatonic, which similarly deserts the limestone to cross the uplands. The presence of important structure planes in these positions would, in the view of the writer, afford the simpler explanation. It will be noted here that there is considerable uniformity in the spacing of the trough lines of this series, especially a_2, a_3, a_4.

---

[1] DAVIS: The Triassic Formation of Connecticut, Eighteenth Ann. Rep. U. S. Geol. Surv., Pt. II, 1898, p. 165.

[2] KÜMMEL: Some Rivers of Connecticut, JOUR. GEOL., Vol. I, p. 379, 1893.

The next most striking series of trough lines is indicated in the course of the Connecticut from Springfield to Hartford (c_1), a distance of twenty-six miles; of the Willimantic (c_2); of the Mt. Hope (c_{2a}); the Little (c_3); and a long stretch of the Quinebaug (c_4). The direction of these trough lines is about N. 5° E., though this is not one of those observed to characterize the faults in the Pomperaug Valley area. Again, the spacing of these trough lines is quite regular if we regard the space between the Connecticut and the Willimantic as a double interval. More striking, perhaps, than any of these trough lines is the one indicated in the series of smaller streams which extend along the line c_5 of the map. These streams are too small to deserve names upon a map of this scale, but some of them are known as Five-Mile River, Whetstone Brook, Moosup River, Mt. Misery Brook, etc. The direction of the series was in fact obtained from them and applied to the other trough lines in the series. This direction, while not an observed fault direction, corresponds to the longer diagonal of two unit orographic blocks of the Pomperaug Valley placed in contact along their shorter sides (see the dotted diagonal in Fig. 1), and thus it fills an important gap in the system of dislocations outlined.

The trough lines d_1, d_2, and d_3, which trend N. ± 15° E., represent a third series. The line d_1, which corresponds in position with no very important stream, is an observed fault of the Pomperaug Valley area (extended), in which area, however, the Pomperaug River adheres closely to its direction; d_2 corresponds closely for a distance of about fifteen miles with the course of the lower Naugatuck; while to the south the lower Housatonic flows in a nearly parallel direction some distance farther to the east. Most striking of this series is the trough line d_3, along which are arranged stretches of the West, the Quinnipiac with its tributary the Ten-Mile, the Farmington with its tributary the Pequabuck (for about fifteen miles), and a minor branch of the Farmington, which enters at its last great bend. This line, except near New Haven, is some distance east of the curving western boundary of the Newark area of the Connecticut valley.

The only important fault line observed to hold to the direction of the N. ± 20° E. faults, which is marked f on the map, follows the Quinnipiac for about fifteen miles and continued northward coincides with the course of the Connecticut for a distance of about six miles.

Following the direction N. ± 33° E. are the trough lines e_1, e_2, e_3, e_4, e_5, and e_6, the latter less marked than the others, and e_4 being an important observed fault in the Pomperaug Valley area. The line e_2 follows for a distance of fifteen miles or more, the middle course of the Housatonic; e_3 is nearly in line with the Croton and the Aspetuck rivers; while e_5 is outlined by the Pine River and the small branch of the Connecticut, which is continuous with the southwesterly flowing elbow of that river at Middletown. The line e_6 shows no striking correspondences on a map of this scale, though midway between it and e_5 the Salmon River, a branch of the Connecticut, for about seven miles follows the direction closely.

The trough lines of the N. ± 5° W. series (b_1, b_2, b_3, etc.), while not prominently marked by the courses of any great streams, save for short distances by the Housatonic, the Naugatuck, and the Connecticut, yet all show on a larger scale map in the minor stream branches many interesting correspondences. As this direction agrees more or less closely with the slope of the Cretaceous plain of erosion of southern New England, the failure of the strong streams to follow this direction is worthy of note.

Though less marked than some of the other series, the trough lines which trend N. ± 90° E. W. seem to be clearly outlined, especially h_1, which passes through the divide of the

Farmington and Quinnipiac at Plainville, and h_2, which follows the easterly course of the Connecticut for a distance below Middletown.

A trough line seems to be indicated in the Salmon River and a branch of the Willimantic (*g*). This direction is N. 48° E. and does not correspond to any observed fault direction in the Pomperaug Valley area. Neither is it the diagonal of any very simple composite block of that area, which otherwise might indicate its relationship to this system.

Conclusions.—In conclusion it may be stated that the rivers of Connecticut seem to indicate by the orientation of their channels the existence of a regular network composed of a number of intersecting series of parallel lines, which for lack of a better term have been designated *trough lines;* and, further, that with two exceptions the more important of these trough lines correspond closely in direction with the directions of fault series observed to characterize the complexly faulted area of Newark rocks in the Pomperaug Valley. Of the two exceptions to the rule, the more noteworthy one (N. ± 5° E.) fills an important gap in the system of faults determined for that area. This study is therefore in its bearing a confirmation of the conclusions arrived at by Kjerulf, Daubrée, and Brögger, who have seen in the orientation of water courses the strong directing influence of geological structure planes.

There are obviously a number of ways in which the dislocations of a region, like the one under consideration, might be made to account for the orientation of stream courses. The direction of streams by the joint or fault planes themselves may be competent to explain the network indicated, more particularly if the streams began their cutting in the soft Newark sediments, which easily sustain secondary fractures near fault planes. That some voids occur along the fault planes of the Pomperaug Valley would seem to be indicated by the fact that these planes have conducted the underground waters to the surface at so many places within the area of the Newark rocks. Tension joints should, however, be more effective than compression joints in the control of drainage lines, if it be assumed with Daubrée that the gaping fissure planes have directed the streams in their courses. The presumptive evidence is, the writer believes, in favor of the former development of the Newark rocks over a much larger territory than that which they now occupy and probably over the entire state of Connecticut.

It is an observation of much interest that the minor twig-like branches of the streams, which in the deeply eroded mass of crystallines must have been adjusted after the capping of sandstones had been removed, show an equally strong tendency with the master streams to follow the special directions indicated by the system as a whole.[1]

The study of the fault system of the Pomperaug Basin offers, however, another rational and natural explanation of the network of streams, provided the assumption is made that the drainage is adjusted to that formed in the geographic cycle which succeeded the deformation of the area. The system of parallel faults has divided the area into vertical triangular, rhombic, or rhomboidal prisms, which stand at different relative altitudes. These prisms are found to be grouped into composite blocks of increasingly higher orders, the peculiar property of each of which is that the average altitude of its component prisms approximates (however roughly) to a fixed value—the composite blocks have an average level surface, although alternate prisms or alternate subordinate blocks for short distances project above or stand below the general level. The initial surface formed by these prisms would be marked by canal-like structure trenches (*Graben*) which follow the directions of fault planes and which have stronger directive power, as regards streams, at the junction of the trenches and at the crossings with the similar trenches of other series.

Although the numerous generally curving fault planes discovered by Davis in his extensive studies of the Newark of the Connecticut valley have here been omitted from consideration, for the reason that no close relationship to the orientation of streams is apparent in their directions, there is no intention thereby to minimize the importance of those studies. The investigation of the smaller Newark area of Connecticut, which by contrast was almost microscopic in its detail, brought out a series of facts which for their interpretation required a totally different theory from the one to which Professor Davis was led by his studies. The two hypotheses have, however, this in common, that the primary cause of the deformation in the Newark rocks is assumed to be the compression of the crust within the area of southern New England by a force of compression, the resultant of which acted in a direction W. N. W. to E. S. E.

---

[1] Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, p. 145, Fig. 52.

The present writer has been led to the conclusion that the courses of large faults within this general area, if not approximately rectilinear, are in reality zigzags, the elements of which are essentially right lines, examples of this kind being by no means rare in, and, in fact, generally characteristic of, the Pomperaug Valley. It is not impossible that many of the larger faults described by Professor Davis, if examined in greater detail, might show this peculiarity, and perhaps also fall into the system which has here and elsewhere been elaborated. The numerous broken lines which are so apparent in the boundaries of the trap hills of the Connecticut valley, as represented on the topographic atlas sheets (*e. g.*, Meriden sheet), would seem to favor this view. It is in any case important, as it would seem to the writer, to consider in two stages the dislocations brought about mainly by a lateral compression of a section of the earth's crust, inasmuch as jointing (the production of planes of separation) is in these cases a necessary prerequisite to faulting (displacement along planes of separation). The modern views of geologists concerning joint planes produced by the shear from lateral compressive stresses are now sufficiently in accord to assume that vertical block faulting takes place along ready-formed planes of jointing. In his description of the faulted area of southern Norway, Brögger[1] has been careful to make this distinction.

---

[1] Loc. cit.

With the explanation of the numerous diversions of rivers from their rectilinear stretches this paper is not especially concerned, although some explanation of such diversions could be found in the peculiarities of a region faulted like that of the Pomperaug Valley. The modern criteria of the physiographer deal adequately with this matter. It is the definite orientation of water courses which the new science seems to have neglected.

William Herbert Hobbs.

COMPOSITE GENESIS OF THE ARKANSAS VALLEY THROUGH THE OZARK HIGHLANDS

On account of its singular course through the Ozark highland region the Arkansas River presents, at the present time, unusual geological interest. Its location in this part of its course, has given rise to two very different opinions regarding the geological age of the highlands; and also regarding the question as to whether there are two distinct uplifts, as has been advocated by the Arkansas geologists, or only one, as has been urged by others who have worked in the region. Recently there have accumulated new data bearing directly upon the problem.

Topographically, the Ozark highlands comprise two imposing, nearly equal, elevated regions, separated from each other by a broad deep trough—the Arkansas River valley. The vast plain surrounding the highlands is about 400 feet above sea level on the eastern side and twice this elevation on the west side. The Arkansas River flows along on the horizon of this general grade-plain. On the south side of the river the highlands rise to heights of nearly 3000 feet above the sea; and on the north to about 1800 feet.

Diverse apparently in topographic expression, lithologic composition, geologic structure, and geological age, the district south of the Arkansas River has been known as the Ouachita Mountains, and that north of the stream the Ozark plateau. On the assumption that there are two distinct uplifts, the river of Arkansas is regarded as forming a natural dividing line between the two regions. At first glance, the simplest explanation for the position of the stream is forced upon the attention. Premising a single uplift, the accounting for the waterway's course meets with difficulties which, from superficial consideration, appear well-nigh unsurmountable. The present note attempts to sum up the evidence going to show that the facts actually sustain the second premise.

In comparing the two districts, it is their differences and not their points of resemblance which are most conspicuous. In the Ouachita region the surface relief is notably mountainous, long ridges and isolated peaks, with wide, flat-bottomed valleys intervening. In the northern district the country is far from appearing mountainous; it is, for the most part, a vast undulating plain, but sharply and deeply dissected around the borders, with the streams flowing in v-shaped valleys. In the south the rocks are more or less indurated or metamorphosed, and cut at intervals by eruptives. Nowhere in the north do the strata show alteration or evidence of the presence of eruptives. The southern district is folded to a marked degree, approaching closely the Appalachian structure; while the northern region is only gently bowed. Regarding the geological ages of the two districts, the Ouachita has been thought to have been upraised towards the close of the Carboniferous; the northern area has been commonly considered as having been an elevated region ever since pre-Cambrian times. The present uplift, however, is now believed to be of very recent origin; and the upward movement is thought to be still in progress.

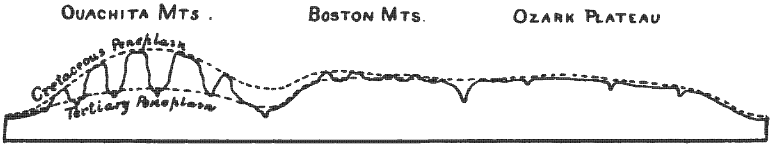


FIG. 1.— Peneplains of the Ozark region.

The physiographical history of the region and the relations of the graded surfaces of the Ozark highlands are best indicated in diagram (Fig. 1).

Two distinct base levels are discernible in the region. They have been called the Cretaceous and the Tertiary peneplains. These titles will be retained for the present. The first of the peneplains rises out of the level savannas of the Mississippi embayment, but soon becomes deeply broken as it rises and passes into the Ouachita region. It is there believed to be continued northward in the mountain summits, which are often flat-topped.[1] The later peneplain is thought to be represented in the intermontane flats which are about 1500 feet lower than tops of the mountains. The floor of the Arkansas valley is coincident with the Tertiary peneplain. Beyond the stream northward the Tertiary surface rises rapidly according to Hershey,[2] and soon in the region of the Boston Mountains the two peneplains practically merge. In Missouri only the Tertiary plain has been distinguished, and this is regarded as forming the general upland surface of the uplift.

It is probable that north of the Boston Mountains it will be exceedingly difficult to differentiate at any point the two peneplains. Present evidence goes to show that during the interval between the formation of the two peneplains in the south the erosion in the north was comparatively slight, and resulted in merely lowering the general surface of the plain already formed during the Cretaceous.

Some time ago it was incidentally stated that the Ozark highlands formed a single unit bowed up from the Red River to the Missouri.[3] The most obvious support for this conclusion is found in the physiographic development of the region. But the evidence is not alone from this source.

The physiographic data would indicate that in the Ozark region the uprising since Cretaceous times has been not only periodical in its character, but that it has been also differential. Lately the movement has been more marked in the north than in the south.

But there were special conditions existing that enabled the Arkansas River to hold its own against the great barrier which started to rise across its course. In a limited belt in this part of the Ozark region an enormous mass of non-resistant clay shales had been deposited in Carboniferous times. The thickness attained was much greater than that of the Carboniferous sediments anywhere else on the American continent, being upward of 20,000 feet, according to Branner.[1] The peculiarities of this great sequence of soft shales have lately been discussed in some detail, and the real significance of the Arkansan series, as it is called, pointed out.[2]

---

[1] Arkansas Geol. Surv., Ann. Rept., 1890, Vol. III.

[2] American Geologist, Vol. XXVII, p. 25, 1901.

[3] Missouri Geol. Surv., Vol. VIII, p. 331, 1895.

Thus, independent of whatever geological structure the Arkansas valley may have, the enormous column of shales was of such character as to enable the great stream to scoop out a trough sufficiently vast and broad to give its topographic form the effect of a depression between two uplifts.

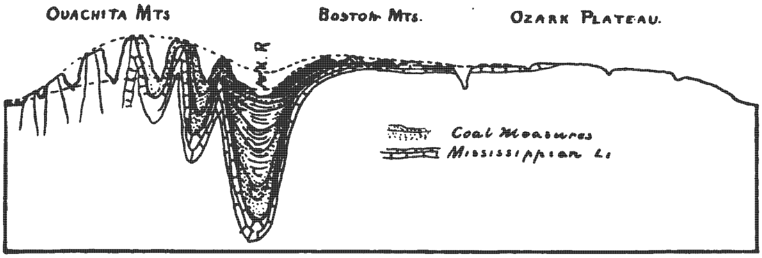


FIG. 2.—Stratigraphy of the Ozark Highlands.

There is another deceptive feature connected with the valley of the Arkansas, that must be taken into consideration. Besides being a topographical trough, the valley is also a structural trough. A broad and shallow syncline stretches from the crest of the Boston Mountains to the first range of the Ouachitas. The strata closely folded in the extreme southern part of the highland district spread out rapidly towards the north until they form gentle undulations that are so characteristic of other parts of the Mississippi basin. The Ozark arch in Missouri constitutes the last great swell northward. Its southern limb passes into the broad syncline which contains the Arkansas valley. This relationship of structure is represented by a north and south cross section (Fig. 2).

The operation of different geological processes may be either all compensating, or all cumulative in their effects. Between the two extremes the sum of the antagonistic tendencies may have very variable values. The present valley of the Arkansas River as it crosses the Ozark highlands is a noteworthy illustration in which the combined effects of perfectly independent processes are curiously cumulative in character. It is on this account chiefly that the real facts concerning the development of the great uplift have been so largely obscured.

---

[1] Am. Jour. Sci., (4), Vol. II, p. 235, 1896.

[2] Bull. Geol. Soc. America, Vol. XII, p. 173, 1901.

Summing up: The different geological conditions when the Arkansas River initiated its course across the Ozark region, (1) an undeformed lowland flat in which the strata had been folded to a marked degree before being beveled and the country reduced to the state of a peneplain, (2) a remarkable, yet narrow, belt, bordered on either side by resistant rocks, of soft shales of prodigious thickness which, when a new epoch of uprising was inaugurated, enabled the stream to easily keep its channel down to the general base level of the country surrounding the uplift, and (3) a broad structural trough, which, however, was only one of many synclines nearby and parallel to it—were highly cumulative in effect in imparting to the uplift the present aspect of twin elevations. By this singular combination of geological conditions the Arkansas River instead of being forced to turn aside by the great topographic dome which, out of the Cretaceous peneplain, arose athwart its path, was able to saw in two the arching strata.

Topographically, the Ozark highlands form two distinct elevated regions. Structurally as well as topographically the Arkansas valley is a trough. But structurally the Ozark highlands, as a whole, form an immense dome bowed from the Red River to the Missouri.

CHARLES R. KEYES.

A SECOND CONTRIBUTION TO THE NATURAL HISTORY OF MARL[1]

THE writer recently published a paper on the relation of algae to marl deposits.[2] Since it appeared, continued investigation has led to the discovery of additional confirmatory evidence that the close relationship there pointed out of the algae, especially Chara, to marl or lake lime deposits, exists to even a greater extent than was suspected.

Experimental work has been conducted along three lines, all of which have been fairly productive of results, and a brief account of this work may be of interest.

First, a series of mechanical analyses of typical white marl from different localities were made. The method of analysis used was a simple one, a modification of the beaker method used in soil analysis. The sample, chosen at random from a large specimen from the deposit under investigation, was dried in an air bath at 110° C. for sufficient time to remove any included moisture, and weighed. It was then mixed with distilled water in a large beaker and thoroughly stirred with a rubber-tipped glass rod, care being taken to stir it until all lumps caused by the adhesion of the finer particles to the coarser were broken up Care was also taken that no more crushing should take place than was absolutely necessary. After all lumps were disintegrated, the water, with the finer particles suspended in it, was poured off into another beaker and fresh water was added to the first and the material was again stirred. This was continued until water poured into the first beaker was nearly free from finer matter and became clear on standing a few moments. The coarse material left in the bottom of the beaker was dried, sorted into various grades by a series of sieves and each grade weighed.

---

[1] Printed by permission of ALFRED C. LANE, State Geologist of Michigan.

[2] JOUR. GEOL., Vol. VIII, No. 6. September–October 1900.

The finer material was also sorted by stirring, settling, and decantation, and the matter of different degrees of fineness dried and weighed. The finest matter was usually separated from the water by filtering through a dried and weighed filter, and the water concentrated by evaporation and again filtered to remove any of the calcium carbonate dissolved in the various processes, and the final residue of water was evaporated in a watch glass and weighed. An exceedingly interesting feature of this latter experiment was the finding of a water soluble calcium salt, in small proportion, it is true, but still easily weighable and not to be neglected. The results of such an analysis of a sample from the Cedar Lake marl beds in Montcalm county, Mich., gave the following results. The sample used was collected from a hole made with a spade by cutting away the turf over the marl, then taking out sufficient marl to be sure that there was no peat or other surface matter present and the material used taken from a spadeful thrown out from two or three feet below this level. From this sample about thirty grams were taken and treated as described above, and after the finer material had been separated from the coarser by washing and drying, the latter was passed through a set of standard gauge sieves, twenty, forty, sixty, eighty, and one hundred meshes to the linear inch, after which all shells and recognizable shell fragments, sand grains and vegetable débris, up to the sixty-mesh siftings, were removed and weighed separately. This gave the following grades: (1) Material too coarse to pass through the twenty-mesh sieve, (2) that held by the forty-mesh, (3) that held by the sixty-mesh, (4) that held by the eighty-mesh, (5) that held by the hundred-mesh, (6) that which passed through the hundred-mesh, (7) that which was filtered out, (8) water soluble salts, (9) shells, shell fragments, and miscellaneous matter.

The following is the result of the analysis of Cedar Lade marl made and graded as described:

Grade (1)	32.25 %
(2)	6.06
(3)	7.58
(4)	2.90
(5)	4.81
(6)	15.64
(7) (8)	30.52[1]
(9)	0.28
	100.04

A second analysis was made from a specimen made up of twenty samples taken by boring with an auger over about one-half of the deposit at Littlefield Lake, Isabella county, most of the samples coming from a depth of at least twenty feet, six to eight meters below the surface of the deposit. This analysis gave the following results:

Grade (1)	31.52 %
(2)	14.48
(3)	12.76
(4)	2.56
(5)	6.74
(6) (7)	30.42
(8)	0.27[2]
(9)	1.04
	99.79

A third sample, from the holdings of the Michigan Portland Cement Company at Coldwater, Mich., a fine high grade white marl, very powdery, gave the following: Weight of sample, 20.— grams.

Grade (1)	0.36 %
(2)	3.53
(3)	6.51
(4)	3.34
(5)	6.44
(6)	28.99
(7)	49.12
(8)	Not determined.
(9)	0.69
Loss and soluble matter (by difference)	1.02
	100.00

---

[1] In this case determined by drying down the residue and weighing.

[2] The soluble matter contains a certain undetermined amount of alkaline chlorides as well as a soluble calcium salt.

These samples represent (1) central, (2) north central, and (3) southern parts of the lower peninsula respectively, and may be taken as typical of the marl deposits of Michigan. When it is stated that, in general, it is easily possible to recognize with a simple microscope the particles which are held by the one hundred-mesh sieve, or even those which pass through it, if the finer matter has been carefully separated by washing, as characteristic Chara incrustation or Schizothrix concretions, it will be seen that these results show conclusively that a large part of the marl from these three samples is identifiable as of algal origin, and studies of the marls from other localities give similar results.

The Coldwater sample (3) was exceedingly fine in texture, and it was difficult to avoid loss in sorting and weighing, as every current of air carried away some of the particles, and some also adhered to sieves and weighing dishes in spite of all precautions. Even this sample shows nearly 50 per cent. of easily identified Chara incrustation. The fineness of the particles in a given marl bed varies much in different parts of the bed, and the degree of fineness is probably chiefly dependent upon the conditions of current and wave action under which the bed was formed, that which was deposited where the wave or current action was strong being coarser than that in stiller water or that on the lee side of exposed banks. This fact was noted at Littlefield Lake when samples of marl were collected along exposed shores above the wave line, which were 95 per cent. coarse fragments of Chara incrustation and Schizothrix nodules, while in other parts of the shore line the marl was of such fineness that it was like fine, white clay. The fragments of the Chara incrustation are generally easily recognized even when of minute size, because they preserve, usually very perfectly, the peculiar form of the stem and branches of the plant. This structure of the stem and branches is, in brief, a series of small tubes, grouped about a larger central one, and is easily seen with the unaided eye in larger fragments. Even when the tubes have been crushed, as is the case with many of the thinner ones, it is frequently possible to recognize fragments of them with the compound microscope. Finally the incrustation is distinctly crystalline in ultimate form of the constituent particles, and when it has disintegrated the crystals and their fragments are found to constitute a large per cent. of the finer particles of the resulting marl. On the growing tips of the younger branches and the leaves of Chara, numbers of isolated crystals of calcium carbonate may be seen. Farther back on stems and branches the crystals become more numerous, then coalesce into a thin, fragile covering, and finally on the lower part of the plant the covering becomes dense and thick. It is evident therefore that the decay of the younger parts of the plants would furnish a mass of more or less free or loosely aggregated crystals of microscopic size, which would retain their crystalline form, in some degree at least, for an indefinite time and be recognizable, hence the presence of microcrystals in marl may furnish additional evidence as to the origin of the deposits.

The larger fragments of Chara incrustation as found in marl are frequently much thicker and heavier than any which occur among fragments of recent origin, *i. e.*, those obtained from any part of living, vigorously growing Chara from the beds of the plant existing in ponds from which the marl may have been obtained. While this subject needs further investigation, it is probable that such thickened incrustations have originated in several ways, the principal ones being, if the writer's notes have any bearing on the subject, as follows:

1. On short, stunted plants that grow for a long time on unfavorable soil, such as sand or pure marl. Such plants have relatively very short internodes and generally thick incrustations, much thicker than those on plants growing normally.

2. From the growth of the lime-secreting, blue-green algae, such as Schizothrix, Rivularia, etc., either upon living chara or upon the fragments of broken incrustation, as a nucleus. Such a growth might produce considerable thickening of the Chara incrustation.

3. From the inclusion of the fragments within the nodules

formed by the growth of the incrusting blue-green algae, in shallow water, and the subsequent destruction of the nodules by wave or other disintegrating action. In this case a thickened fragment may be left either free or attached to other material. Several fragments may be cemented together, and such aggregations have been observed.

4. By the deposition of calcium carbonate on fragments of incrustation, the source of the salt deposited being soluble calcium-organic compounds left free in the water by the decay of dead Chara, the precipitation being caused by the reducing action of chemical compounds derived from the decay of organic matter or the growth of bacteria. It may be conceived also that the calcium carbonate thus deposited might also act as a cementing material to fasten the finer particles of marl to the incrustation as a nucleus.

5. By the deposition in more or less coarsely crystalline form of calcium carbonate which is dissolved by water percolating through the marl. This is probably considerable in amount and takes place in a manner analogous to, if not identical with, the formation of concretions in clays and shales. It is probable that in this way the crystals may be formed, which rather rarely are found filling the cavities in the Chara incrustations, left by the large axial cells of the plant. The fact that in the great majority of cases these cell cavities are entirely empty or are simply mechanically filled with fine particles of marl, is a most serious objection to considering that this form of chemical precipitation is an important one in the history of marl, but that it is occasionally operative is extremely probable.

6. It is possible that the thick incrustations may have been formed at some earlier period in the history of the lakes when conditions for the development of the plant forms and their activities were greater. This is not probable however, for the thick incrustations are often found from the surface of the marl beds throughout the entire deposits.

In addition to the marl analyses given above a check analysis was made of a specimen of material made up from the washings and fragments of a mass of Chara plants collected from Cedar Lake, and allowed to die slowly and to break up in water kept cold and fresh by conducting a small stream from the hydrant through it. The plants gradually died, broke up, and settled to the bottom of the containing vessel and seemed to undergo farther disintegration there from the growth of fungi, eventually forming a relatively finely divided deposit which was of rather dark color, when wet. A quantity of this was dried at 100°C., some of the longer and larger fragments of stems were removed, and the residue was weighed and subjected to the same treatment as the marl samples. The analysis gave the following:

Grade (1)	1.12%
(2)	24.43
(3)	14.63
(4)	8.26
(5)	7.81
(6) (7)	33.83
(8)	0.39
(9)	0.12
Soluble organic matter and loss	9.41
	100.00

It will be seen that nearly as much fine matter was present in this material as in the finest of the marls analyzed, and that the finer grades of sifted material are quite as well represented as in the finer marl. The material is somewhat more bulky for a given weight and is perhaps slightly darker in color, but not much more so than many samples of marl.

Grade for grade it is identical in appearance and structure to the marl samples, and the only possible difference that can be detected is the slightly green tint and the organic matter present in the plant residue. It is also noticeable that the larger pieces do not show as thick an incrustation as do the larger pieces from the marl samples and, of course, Schizothrix and other coarse matter is not present.

It will be seen by inspecting the analyses, that shells and recognizable shell fragments are but a very insignificant part of the total quantity of the marl. It is surprisingly small when all things are taken into account. While it is probably true that not all the minute shell fragments have been separated in any of these analyses, it is also true that the weight of such overlooked particles is more than counterbalanced by marl fragments which are included within the cavities of the whole shells, and adhere to both broken and whole shells in crevices and sculpturings in such a way as to refuse to become separated in the processes of washing out the marl. The whole shells are mainly small, fragile forms, many of them immature, and it is evident that they would be broken by any action that would crush the Chara incrustation.

A second line of investigation took into consideration the milky appearance of the waters of some marl lakes. This has been considered by some investigators as possibly due to the presence of calcium carbonate precipitated from the water either by the liberation of dissolved carbon dioxid from the water and hence from the calcium bicarbonate or by change of temperature of the water after it has reached the lakes.

The writer has not found among the marl lakes of the southern peninsula of Michigan that those with turbid water were common, even where marl banks were apparently forming with considerable rapidity.

"Merl" or Marl Lake in Montcalm county, situated on the same stream as Cedar Lake and a mile or more below it, is, however, one of the lakes in which the water is usually of almost milky whiteness, and has sufficient suspended matter in it to render it nearly opaque for depths of a meter or a little more. The conditions in this lake are widely different from those at Cedar Lake and other marl lakes in the vicinity and are suggestive of the cause of the turbidity. At Cedar Lake there is a border of grassy or sedgy marsh extending around the lake on three sides and generally underlaid by marl, and the lake bottom slopes sharply and abruptly from the edge of the marsh to a depth of at least ten meters. In other words the lake is simply a deep hole, with steep sides, and perhaps represents the deepest part of the more extensive lake which formerly occupied the area included by the marsh and marl beds. This marsh covering is general on the marl beds of the region and the lake may be said to be a typical marl lake for the locality in which it lies, for there are several others near by which are practically identical in essential points of structure.

At Marl Lake, however, the filling of the lake has not reached the same stage. There is practically no open marsh, but the lake is shallow for seventy-five or a hundred meters from the shore, then abruptly deepens to an undetermined depth over a relatively small area. The bottom over the shallow area is of pure white marl, and the water is apparently not more than sixty or seventy centimeters deep at the margin of the central hole, while near the shore it is scarcely one-third as deep. In brief, here is a lake in which there is a broad platform of marl surrounding a deep hole, which again is all that remains of the deep water of a lake which is filling with marl. Boring shows that the bed of the lake is nearly as far below the surface under the marl platform, as where the marl has not yet been deposited.

Upon the shoreward edges of the platform and in small areas farther out upon it, the turf-forming plants are beginning to establish themselves, but as yet they have not made any marked impression, seeming to have a hard struggle to get a foothold. The conditions are then a broad area of shallow water overlying a wide platform of marl, which, if a strong wind should reach it, would be stirred to its depths, and with it the lighter parts of the marl upon which it rests. The marl thus stirred up, in turn, is carried to all parts of the lake by surface and other currents and makes the water turbid. These facts led to an investigation as to the rapidity with which marl, once stirred up, would settle out of perfectly still water, and some interesting results were obtained. The experiments were made as follows: (1) A glass tube 1.58 meters long and 2.5 centimeters wide was filled with distilled water, into which a quantity of finely divided marl was turned and the tube was shaken to insure a thorough mixing of water and marl. The tube was then clamped into a vertical position and left perfectly still until the marl had settled out, notes being made, daily at first, of the rate of settling. In the beginning, the heavier particles settled rapidly, forming, as does clay in settling from water with which it is mixed, stratification planes, which, however, after a few days disappeared, and only the lighter parts of the marl remained in suspension. These were distinctly visible for five weeks, on looking through the tube towards a window, and at the end of six weeks, a black object lowered into the tube in a well-lighted room, was not visible beyond ninety centimeters from the surface of the water. (2) A glass cylinder with a foot, 38^{cm} high and 7^{cm} wide, having a capacity of a little more than a liter was nearly filled with distilled water and the residue from the washings of a sample used in analysis was thoroughly mixed with it, and set aside, notes being made as before. This material subsided rather more slowly than the other, and at the end of ten weeks, under daylight illumination, the bottom of the vessel was barely visible when one looked down through the water from above.

The results obtained by Barus[1] in his work on the subsidence of solid matter into suspension, in liquids, show that settling is much more rapid in water containing dissolved salts, even small proportion, than in distilled water, and the foregoing experiments were checked as follows: (1) A cylinder about the size of the one used in the second experiment was filled with water in which a small amount of calcium chlorid had been dissolved, and ammonium carbonate was added until a precipitate was formed. This was stirred thoroughly and left to settle. In three days the precipitate had fully subsided and the liquid was clear. (2) Two cylinders of equal size were filled, one with distilled water, the other with water from a river fed, in part, by marl lakes. Equal quantities of fine marl were shaken up with the water and the rate of settling was compared. The marl was not as fine as that used in the other studies and settled more rapidly. The river water was clear in fifteen days, while the distilled water was not clear when the experiment terminated, but was nearly so, showing that the subsidence was not quite so rapid in distilled water as in natural lake or river water.

---

[1] CARL BARUS: "Subsidence of Fine Solid Particles in Liquids." Bull. of the U. S. Geol. Surv., No. 36.

These results indicate that, if for any cause the marl in a marl lake is stirred up effectually, as it may be in those where the beds are exposed to wave action, the water will remain turbid for some time; even in summer time the chances are that there will be sufficiently frequent high winds to keep the water always turbid. It may be stated that in some of the lakes which have been studied by the writer, the marl beds have filled the entire lake to within a fraction of a meter of the surface of the water, with some parts only a few centimeters deep. Until such shallows are occupied by vegetation the water is likely to be turbid from the mechanical action of waves upon the deposits. At Littlefield Lake, described elsewhere,[1] the water is only slightly turbid, although there are extensive shallows and exposed banks, but there the body of water is extensive and of considerable depth, while the greater part of the exposed marl is granular and the particles too coarse to be held long in suspension, and the finer deposits too small and too well protected to be reached by effective waves, so that the amount of suspended marl is not great enough to produce marked turbidity in the entire body of water.

It may be worthy of note that the residue of suspended matter, filtered out from the sample of Chara fragments (analysis (4) above) was sufficiently fine to give a marked turbidity to distilled water for several days, and at the time of filtering had not subsided, demonstrating the fact that very finely divided particles may originate from the simple breaking up of the Chara plants by ordinary decomposition of the vegetable matter.

It is difficult to account for the fact that the deeper parts of marl lakes are generally free from any thick deposits of a calcareous nature. Lack of records of sufficient exploration makes any statement purely tentative, but about seven to nine meters[2] seems to be the limit of depth of recorded occurrence of Chara plants. The remains of the plants, then, would only accumulate, in place, above that depth, and the material reaching greater depths would be that held in suspension in the water, and hence be relatively very small in quantity and accumulate slowly. A possible additional cause of slow accumulation is that in the greater depths, *i. e.*, over ten meters, the greater abundance of dissolved carbon dioxid held in solution by pressure dissolves the finer particles of marl which reach these depths.

---

[1] C. A. Davis: "A Remarkable Marl Lake," Jour. Geol., Vol. VIII, No. 6.

[2] Wesenberg-Lund: Lake-Lime, Pea Ore, Lake Gytje. Saertryk af Meddelelser fra Dansk Geologisk Forening, No. 7, p. 156.

From these investigations it seems (1) that marl, even of the very white pulverulent type, is really made up of a mixture of coarser and finer matter covered up and concealed by the finer particles, which act as the binding material. (2) That the coarser material is present in the proportion of from 50 to 95 per cent. (3) That this coarser material is easily recognizable with the unaided eye and hand lens, as the incrustation produced on the algae, Schizothrix and Chara, principally the latter, to particles less than one one-hundredth of an inch in diameter. (4) That the finer matter is largely recognizable under the compound microscope as crystalline in structure, and is derived from the algal incrustation by the breaking up, through decay of the plants, of the thinner and more fragile parts, or by disintegration of the younger parts not fully covered. (5) That some of this finer matter is capable of remaining suspended in water a sufficiently long time, after being shaken up with it, to make it unnecessary to advance any other hypothesis to explain the turbidity of the waters of some marl lakes, than that it is caused by mechanical stirring up the marl by wave or other agency. (6) That shells and shell remains are not important factors in the production of the marl beds which are of largest extent. (7) That there is in marl a small amount of a water soluble calcium salt, readily soluble in distilled water, after complete evaporation.

---

[2] A. J. PIETERS: Plants of Lake St. Clair, Bull. Mich. Fish Commission, No. 2, p. 6.

Studies were undertaken to determine the method of concentration and precipitation of the calcium carbonate by Chara.

As has already been indicated elsewhere, the calcium carbonate is present on the outside of the plant as an incrustation, and this is made up of crystals, which are rather remote and scattered on the growing parts of the plants, and form a complete covering on the older parts, which is uniformly thicker on the basal joints of the stems than it is on the upper ones. Considering the hypothesis that the deposition of the salt was the result of purely external chemical action as not fully capable of satisfying all the existing conditions, the formation of the incrustation was taken up as a biological problem, and an investigation was made upon the cell contents of Chara, first, microscopically by the study of thin sections. Various parts of the plant were sectioned while still living, and the attempt was made to find out if the calcium carbonate was present as a part of the cell contents in recognizable crystalline form. Various parts of the plant were examined, but no crystals undoubtedly in place among the contents of the cells were observed, although numbers were to be seen on outside walls of all cells.

Next an attempt was made to determine the presence of the calcium in soluble form in the cell contents, by the use of dilute neutral solution of ammonium oxalate. An immediate response to the test was received by the formation of large numbers of minute, characteristic, octahedral crystals of calcium oxalate on the surface and imbedded in the contracted protoplasmic contents of the cell. The number of these crystals was so large, and they were so evenly distributed through the cell contents, that it was evident that a large amount of some soluble calcium salt was diffused through the cell sap of the plant. The next step was to isolate this compound and to determine its composition. A considerable quantity of the growing tips of Chara were rubbed up in a mortar and the pulp was thoroughly extracted with distilled water. This water extract was filtered and tested to determine the presence of calcium and an abundant precipitate obtained by using ammonium oxalate, which, on being separated and tested, proved to be calcium oxalate. It was evident that the calcium salt in the plant was stable and readily soluble in water. This latter fact was farther demonstrated by evaporating some of the extract to dryness and again taking it up with water. Almost the entire amount of the calcium salt was redissolved, only a small portion of it becoming insoluble and precipitating as the carbonate. This ready solubility demonstrated the fact that the salt was not derived from the incrustation on portions of the plant used, and the same fact excluded from the list of possible compounds, salts of some of the mere common organic acids found in plant juices, which are insoluble.

Qualitative chemical tests were, however, made to determine, if possible, whether any of these acids were present with negative results, and it was demonstrated by this means that there was but a single salt present and not a mixture. Search was then made to determine the acid present, and a result obtained which was so unexpected that it was seriously questioned and the work was gone over again. The second result confirmed the the first and the work of ascertaining the correctness of these two results was turned over to Mr. F. E. West, Instructor in Chemistry in Alma College, who had had special training and much practice in organic analysis. His work was done entirely independently, with material gathered at a different season, and by another method of analysis, but his results were identical with my own, and show that calcium exists in the water extract of Chara as calcium succinate. The fact that the succinate is one of the few water soluble calcium salts and that there is a soluble salt of the metal in the cell sap of the plant makes it probable that this is the compound of the metal which the plant accumulates in its cells.

It is not possible from actual investigation to explain the method by which the calcium salt is abstracted from the water, where it exists as the acid- or bi-carbonate or the sulphate[1] in small per cent., and is concentrated in the cells of the plant as calcium succinate and later deposited upon the outside of the same cells as the normal or monocarbonate in crystalline form in considerable quantities.

---

[1] It has been shown that Chara decomposes several calcium salts, the sulphate among others.

Some culture experiments which were undertaken by the writer to determine under what conditions of soil, light, and temperature Chara thrives best, incidentally demonstrated that the plant actually gets its lime from the water and not from the soil. One of the soils which was used as a substratum in which to grow plants was pure quartz sea-sand which had been washed with acid to remove any traces of calcium salt which might be present. The plants grew in this medium readily, and on the newer parts developed nearly, if not quite, as many calcium carbonate crystals as plants growing in pure marl. It should be apparent, however, to even the casual observer that the plants cannot take all the lime they precipitate from the soil, or even a considerable part of it, for if they did the marl beds, being made up principally of Chara remains, would never have accumulated, for the material would have been used over and over again and could not increase much in amount, if it increased at all. In the present state of our knowledge of the life processes of aquatic plants, it seems hardly possible to state the probable method of the formation of the calcium succinate, or even the probable use of it to the plant, and no attempt will be made by the writer in the present paper to do so. It does seem probable, however, that this compound accumulates in the cells, until it reaches sufficient density to begin to diffuse through the cell walls by osmosis. Outside the cells, or in its passage through the walls, it is decomposed directly into the carbonate, possibly by oxidation of the succinic acid by free oxygen given off by the plants, possibly by some substance in the cell walls, or, more probably, by the decomposition of the acid by some of the organic compounds in the water, such as the organic ferments, due to bacterial growth in the organic débris at the bottom of the mass of growing Chara. The water extract of Chara rapidly changes on standing, undergoing putrefactive decomposition, becomes exceedingly offensive in odors developed, and calcium carbonate crystallizes out on the bottom and sides of the containing vessel, while the succinic acid disappears, gas, possibly carbon dioxid, being given off more or less abundantly. Whether these changes takes place on the outside of the living plants, in the cell walls, or in the water surrounding the plants has not yet been determined.

Sufficient evidence is here presented, however, if the writer's conclusions are correct, to show that the plants under discussion are active agents in the concentration of calcium salts in the fresh water lakes of Michigan, and that they alone have produced a very large part of the marl which has accumulated in these lakes. It seems probable also that the principles developed by these studies are of very wide application in working out problems presented by formations developed under similar conditions elsewhere.

CHARLES A. DAVIS.

ALMA COLLEGE,
July 1, 1901.

PERKNITE (LIME-MAGNESIA ROCKS)[1]

THERE are sometimes associated with diorites, gabbros and peridotites, dark rocks composed largely, or entirely, of monoclinic amphibole or pyroxene, or both. These rocks differ mineralogically from diorites and gabbros, in containing little or no feldspar, and from peridotites in containing rhombic pyroxine or olivine in relatively small amount, if present at all. Chemically these rocks contain less alumina than diorites and gabbros, and less magnesia than peridotites. They are low in alumina and in the alkalis, moderately rich in lime, magnesia, and the iron oxides.

The chief constituents of perknite are monoclinic amphibole and monoclinic pyroxene; the secondary constituents rhombic pyroxene, olivine and feldspar; the accessories biotite, iron ore, etc., but only one of the primary constituents may be present with none of the secondary constituents or accessories. The existence of this group of rocks has long been recognized, but from their occurrence usually in small masses, and from the fact that many of them are of simple composition so that the self-explanatory names pyroxenite and amphibolite or hornblendite have answered, they have never been grouped together under one name.

In the State of New York[2] and in California[3] there are rocks containing both monoclinic pyroxene and amphibole as principal constituents, and doubtless this is likewise the case in many other parts of the world. Moreover, in California such rocks form areas of geological importance. There is, therefore, some reason in grouping all of these lime-magnesia rocks under a common name. It is proposed to call the group *perknite* from the Greek word περκνος, meaning dark. It will include granolites of the following specific names:

---

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] G. H. WILLIAMS: Am. Jour. Sci., Vol. XXXI, 1886, p. 40.

[3] TURNER: Am. Jour. Sci., Vol. V, 1898, p. 423. Turner and Ransome. Sonora folio.

Pyroxenite.
Hornblendite (Williams).
Websterite (Diallage and ortho-rhombic pyroxene) (Williams).
Diallagite.
Hornblende-hypersthene rock (Merrill).
Amphibole-pyroxene rock (Turner).

The group may be graphically represented by the method employed by Hobbs[1] and his representation of a composite pyroxenite will approximate to that of a typical perknite. The following table of analyses will give the reader a notion of the composition of the rocks which may be properly included in this group.

1. *Hornblendite.*—Geo. Steiger, analyst. This partial analysis is here published for the first time. The rock is from a dike cutting through the basement complex and overlying Cambrian rocks, 2 km north of Silver Peak village, in Esmeralda county, Nev. It is composed chiefly of green hornblende with some feldspar. The rock grades into a basic diorite.

2. *Amphibole-pyroxene rock.*—W. F. Hillebrand, analyst. Not before published. Rocks of this type are very abundant in Mariposa county, Cal. Mr. F. M. Anderson, of the University of California, has likewise collected them in northern California. This rock in its typical development is composed of original pyroxene and amphibole in grains of nearly equal size, with a little quartz and pyrrhotite. Scattered through the rock are phenocrysts about one centimeter in diameter, of brown amphibole, which contain in a poikilitic manner, as inclusions, the constituents of the groundmass.

3. *Perknite* (author's name, *peridotite*).—Belchertown. Bull. U. S. Geol. Survey, No. 168, p. 30. L. G. Eakins, analyst. The rock is composed of hornblende, pyroxene, biotite, olivine and magnetite.

---

[1] JOUR. GEOL., Vol. VIII, 1900, p. 14.

ANALYSES OF PERKNITES; LIME-MAGNESIA ROCKS.

Name	I Hornblendite	II Amphibole-pyroxene rock	III Perknite	IV Pyroxonite	V Websterite	VI Websterite	VII Composite pyroxonite
SiO_2	46.28	48.04	48.63	50.80	53.25	53.21	52.58
Al_2O_3	.....	7.82	5.32	3.40	2.80	1.94	3.69
Fe_2O_3	.....	2.01	2.91	1.39	.69	1.44	1.90
FeO	.....	9.32[1]	3.90	8.11	5.93	7.92	6.50
MgO	19.54	13.33	21.79	22.77	19.91	20.78	20.86
CaO	9.91	13.01	13.04	12.31	16.22	13.12	13.23
Na_2O	2.21	.69	.34	trace	.19	.11	.22
K_2O	1.89	.48	.23		trace	.07	.10
$H_2O-110°C$	.....	.17	2.81	.52	.05	.14	.57
$H_2O+110°C$	.....	2.90			.24	.87	
TiO_2	.....	1.16	.47	none	.....	.26	.11
ZrO_2	.....	.....	.....	.....	.....	trace	....
CO_2	.....	none	trace	.....	.....	.10	....
P_2O_5	.....	trace	.21	trace	.....	trace	....
SO_3	.....	.23[2]	.....	trace	.....	.....	....
S	.....	.90	.....	Cl. .24	.....	FeS_2 .03	....
V_2O_3	.....	.....	.....	.....	.....	.03	....
Cr_2O_3	.....	.90	.36	.32	.54	.20	....
NiO	.....	.....	.....	.....	.07	NiO + CoO .03	....
MnO	.....	none	.12	.17	.09	.22	.11
BaO	.....	none	trace	.....	.....	none	other constituents
SrO	.....	.....	.....	.....	.....	none	.50
Li_2O	.....	.....	.....	.....	.....	trace	....
Total	.....	100.06	100.13	100.03	99.98	100.47	100.49
Less O	.....	.45					
		99.61					

4. *Pyroxenite.*—Johnnycake road, Baltimore. Bull. U. S. Geol. Survey, No. 168, p. 42. Composed entirely of hypersthene and diallage.

5. *Websterite.*—From Mt. Diablo. W. H. Melville, analyst. Bull U. S. Geol. Survey, No. 168, p. 213, and Bull. Geol. Soc. Am., Vol. II, p. 406; analysis No. 242. The rock is composed of orthorhombic pyroxene and diallage.

---

[1] Owing to analytical reasons this determination of ferrous iron is unsatisfactory.—W. F. Hillebrand.

[2] This determination somewhat doubtful.—W. F. H.

6. *Websterite.*—Oakwood, Cecil county, Md. Composed of hypersthene and diallage. W. F. Hillebrand, analyst. Bull. U. S. Geol. Survey, No. 168, p. 43.

7. *Composite pyroxenite.*—Hobbs, Jour. Geol., Vol. VIII, p. 30. This analysis is a composite from three analyses of pyroxenites, and one analysis of a hornblende-hypersthene rock from Gallatin county, Mont.

Professor J. S. Diller, in his bulletin on "The Educational Series of Rock Specimens,"[1] introduces three specimens which would fall into the perknite group.

No. 110, a pyroxenite, is described by Professor George H. Williams.

No. 111, feldspathic peridotite, is described by Professor George H. Williams.

No. 113, Cortlandite (hornblende-peridotite), is described by Williams and Iddings. The rock is composed of brown hornblende, olivine, pyroxene, biotite, feldspar, and magnetite.

Some rocks that have been termed wehrlite will fall also into this group.

EFFUSIVE AND DIKE ROCKS

Corresponding to the plutonic group of perknite there undoubtedly occur effusive and dike rocks. Professor Rosenbusch regards hornblende-picrites as effusive, and some of these have the chemical and mineral composition of perknite. This will also be true of augitites, since in these augite or monoclinic pyroxene is the chief constituent.

Professor J. P. Iddings has been kind enough to criticise the above paper and calls my attention to the fact that my definition of perknite would bring into the group the kimberlite of Kentucky with 9.46 per cent. of lime, and the kimberlite of South Africa with 9.60 per cent. of lime, as wellas the amphibole-peridotite of Schriesheim with 7.22 per cent. of lime. He also calls attention to the fact that with hypersthene-enstatite rocks there may be very little lime present and yet they would not be peridotite. This brings us to the re-definition of peridotite, and I should define a peridotite chemically as a magnesia rock with usually less than 6 per cent. of lime. This would put a rock composed entirely of hypersthene or enstatite with the peridotites, where they certainly belong chemically.

---

[1] Bull. U. S. Geol. Surv., No. 168.

H. W. TURNER.

SAN FRANCISCO, CAL.,
June 20, 1901.

THE BORDER-LINE BETWEEN PALEOZOIC AND MESOZOIC IN WESTERN AMERICA

THERE have been in recent years in America many controversies as to the Silurian-Devonian and the Devonian-Carboniferous boundaries; but American geologists have always felt secure as to the line of demarcation between the Paleozoic and the Mesozoic. This has always been thought to be marked by a grand chasm, a hiatus in stratigraphy and a break in life, accompanying a great change in physical geography, all of which is true of the region east of the Rocky Mountains.

But later discoveries in the Great Basin region have shown that the gap is at least partly filled out by marine sediments, and that the hiatus is not universal in America. The most important of these discoveries was the finding of marine Permian in northern Texas, with forms suggestive of the Mesozoic types of life, and the finding in southeastern Idaho of marine Lower Trias, with a fauna reminiscent of the Paleozoic.

Recently there has been evident among geologists a tendency to revert to first conditions in determining the boundaries of geologic systems. They have been inclined to use unconformities as the dividing lines between geologic groups, and to look upon geologic systems as realities, and not mere names for the convenience of stratigraphers. This must mean that they regard the geologic events that delimited the systems as of world-wide effectiveness, or even of cosmic origin. But almost every trangression of the sea has been found to be balanced by a retreat elsewhere, every uplift to have its correlative subsidence. And in still other parts of the earth there may have been neither uplift nor subsidence. Even the Appalachian revolution did not effect the western Carboniferous Sea, and this is generally admitted to have been one of the greatest events in the dynamic history of North America.

In defining the upper Paleozoic and the lower Mesozoic no account was taken of conditions of formation, and this has led to endless difficulties in correlation. The Upper Carboniferous was based entirely on lacustrine deposits, and the identification of its marine equivalent is still making trouble for geologists. The Permian was based on a basin deposit, partly lacustrine and partly of brackish water origin, and the recognition of its purely marine types has caused much controversy in Europe and America. The Trias was based at first entirely on the deposits of the Germanic inland sea, and only recently has any uniformity been attained in its correlation and nomenclature.

The greater divisions are now all named, and there is no room for new systems, all geologic time, and possibly something over, being taken up by those already defined. But because the first naming of geologic divisions was based on unconformities, which represented erosion intervals and consequent gaps in the record, further exploration must necessarily bring to light somewhere in the world passage beds between the artificial systems. What rules then shall be followed in the correlation of these passage-beds, or new formations? If the new formations are shown to be the homotaxial equivalents of parts of systems already defined, there can be no question, for faunal or lithologic differences cannot be taken in account in different provinces or regions.

If the new formation, however, lies between two systems, one of which is sharply defined and the other described only vaguely, as including the beds below or above the one with definite boundaries, then the passage-beds must naturally be assigned to the system with a flexible margin.

If both the bordering systems should be definitely bounded, or if neither should be, then one or the other must be stretched to take in the passage-beds, and the assignment will be based on paleontologic relationship to one or the other. But if this relationship should be no closer to one than the other, then priority of assignment would have to decide on the nomenclature of the doubtful beds.

The geologists of India have for many years recognized that in the Himalayas and the Salt Range there was a continuity of life and sedimentation from the Paleozoic into the Mesozoic, and there the line of demarcation has been arbitrary. The stages or zones used in drawing this paleontologic line in India have become types, and are used in interregional correlation wherever similar beds are known. A section is given below of the uppermost Permian and the Lower Trias of India, for convenience of comparison with the American section.

SECTION OF THE PERMIAN AND LOWER TRIAS OF INDIA AFTER WAAGEN, DIENER, AND NOETLING

Trias	Middle	Upper Ceratite limestone.	
	Lower	Ceratite sandstone	Flemingites beds. Stachella beds.
		Otoceras beds	Ceratite marls. Lower Ceratite limestone.
Permian	Upper	Upper Productus limestone, with *Cyclolobus oldhami*, and *Xenaspis carbonaria*.	
		Middle Productus limestone, with *Xenaspis carbonaria*.	
	Lower	Lower Productus limestone, with *Fusulina kattaensis*.	
		Glacial beds.	

Waagen drew the line between Paleozoic and Mesozoic at the base of the Ceratite formation because of a supposed unconformity, and because the Permian types of brachiopods such as *Productus*, *Chonetes*, and the Orthidae have not been found above this line. But the unconformity has since been shown not to exist, and several of the Permian ammonite genera range up into the Ceratite formation, such as *Otoceras*, *Medlicottia* and *Xenaspis*.

The upper Productus limestone is acknowledged to be younger than any known European marine Permian, and the *Otoceras* beds are universally considered to be older than any Trias yet known from Europe; therefore the continuity of sedimentation and life makes it exceedingly difficult to draw a line that will satisfy everybody. And, indeed, if either the Trias or the Permian had been named first in India, there would have been no division of this series.

The Wichita Permian of Texas, while carrying forms such as *Medlicottia*, *Waagenoceras*, and *Popanoceras*, harbingers of the varied Triassic ammonites of later times, contains in its other members so many Paleozoic types that no one would think of classing it in the Mesozoic. There can be no controversy as to its age, which is approximately equivalent to that of the lower Productus limestone of India. It lies conformably on the Coal-measures, and contains many species that have ranged up from the latter.

But above the Wichita Permian lies the great series of the Red Beds. These have been assigned sometimes to the Permian and sometimes to the Trias, and they, doubtless, belong to both. Marine fossils have been found in these Red Beds only in three places. The Geological Survey of Texas[1] found in the Double Mountain formation at the falls of Salt Croton Creek, Kent county, Texas, *Medlicottia*, *Waagenoceras*, and *Pleurophorus*, all akin to forms from the Wichita beds. The writer has examined these forms and recognizes them to be still typically Permian in character, although they are very near the top of the formation. Above these beds lies the fresh water "Dockum" series referred by Cope to the Trias.

C. N. Gould[2] has recently found marine and brackish-water Permian fossils in the Red Beds of Oklahoma, in the Cimmaron series; the forms still being of Paleozoic type, such as *Conocardium*, *Aviculopecten*, *Schizodus*, *Pleurophorus*, and *Bakevellia*. The stratigraphic position of these is equivalent to the Double Mountain beds of Texas, and they belong unequivocally to the Paleozoic.

In the Red Beds of Utah, at Ft. Douglas near Salt Lake City, F. Frech[3] has found *Pleurophorus imbricatus* Waagen, *Allorisma* conf. *elegans* King, *Emondia aspinwallensis* Meek, *Schizodus schlotheimi* King, and *Dalmanella* sp. indet., a fauna that would pass for Paleozoic anywhere, and belongs in the same horizon as the Double Mountain beds of Texas and the Cimmaron series of Oklahoma and Kansas. They are the homotaxial equivalents of the Upper Permian.

---

[1] Geological Survey of Texas, Second Annual Report, 1890. Report on the Geology of Northwestern Texas, by W. F. CUMMINS, p. 408.

[2] JOUR. GEOL., Vol. IX, 1901. No. 4, p. 337.

[3] Lethaea Geognostica, Vol. II, Lieferung 3. 1900, p. 515.

From the close of the Coal-measures the land encroached on the basin-sea by a progressive westward uplift, and the brackish water and basin deposits take a successively higher place in the geologic column towards the west. Thus somewhere in the eastern part of the Great Basin region marine intercalations of Lower Trias may be expected to be found in the Red Beds. Indeed, this formation in southeastern Idaho lies above and conformably upon the marine limestones with a Lower Triassic fauna. It is, then, in the upper part of this Red Beds formation, in the fresh and brackish-water deposits and its rare marine facies, that we are to seek for the transition from Paleozoic to Mesozoic.

C. A. White[1] has described from the Aspen Mountains of Idaho a marine fauna older than any Trias known up to that time in America, and younger than any known Permian. The Meekoceras beds in which this fauna was found he assigned to the Lower Trias. According to A. C. Peale[2] this formation lies conformably upon the Carboniferous, and below the Red Beds. The *Meekoceras* fauna was found near the base of the series, which here has a thickness approximating three thousand feet. The Carboniferous limestone below contained *Productus multistriatus* Meek, which has been found by the writer in the uppermost Paleozoic beds of California, and has been cited as a characteristic fossil of the Permian of northern Europe.

Since that time Professor Alpheus Hyatt and the writer have visited the Meekoceras beds, and their joint collections yielded; *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *Aspidites*, *Flemingites*, *Pseudosageceras*, *Ussuria*, *Ophiceras*, *Clypites*, *Danubites*, *Nannites*, and a number of new genera.

The writer[3] has previously described the Ceratite limestone of the Lower Trias of Inyo county, California. During the past winter he has visited this locality and added a great many species and genera to the collection from that formation. Those now known from there are: *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *M.* conf. *radiosum* Waagen, *M.* conf. *falcatum* Waagen, *M.* aff. *boreale* Diener, *Aspidites*, *Prionolobus*, *Danubites*, *Proptychites*, *Xenaspis*, *Lecanites*, *Nannites*, *Ussuria*, *Pseudosageceras*, and *Clypites*, besides a number of new genera. Several of the species, both new and described, are identical with forms from the *Meekoceras* beds of southeastern Idaho, with no greater difference in the fauna than might be expected in localities separated by six hundred miles.

---

[1] Twelfth Ann. Rep. U. S. Geol. and Geog. Surv. Terr., Part I (1880). Triassic Fossils from Southeastern Idaho.

[2] Bull. U. S. Geol. and Geog. Surv. Terr., Vol. V., No. 1 (1879). Jura-Trias Section of Southeastern Idaho and Western Wyoming, p. 119.

[3] JOUR. GEOL., Vol. VI, No. 8, 1898. Geographic Relations of the Trias of California.

Below the *Meekoceras* beds of Inyo county lie several hundred feet of barren shales, and below these is siliceous limestone containing *Fusulina*. Above the *Meekoceras* beds are eight hundred feet of calcareous shales with impressions of ammonites, and then a few feet of black limestone with *Acrochordiceras*, *Hungarites*, *Tirolites*, *Ceratites*, and *Xenodiscus*, and *Parapopanoceras*, probably belonging to the base of the Middle Trias. The entire series appears to be conformable, from the Upper Carboniferous to the Middle Trias.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite formation of India, and of the homotaxial *Proptychites* beds of Ussuri in eastern Siberia. *Meekoceras*, *Gyronites*, *Koninckites*, *Danubites*, *Proptychites*, and *Ophiceras* are known both in the Ceratite formation of India, and in the Ussuri beds of Siberia; *Pseudosageceras* and *Ussuria* are known elsewhere only in the Ussuri formation; and the species of all these regions are nearly related, in part apparently identical.

It is, therefore, plain that the correlation of the Ceratite formation of India has a direct bearing on the determination of the age of the Meekoceras beds of America. Albert Oppel, who in 1865 described fossils from the Ceratite formation of India, referred them at first to the Jura, and then afterwards to the Trias, as typical Jurassic beds were found considerably above them. But before this, in 1863, de Koninck, who also described a number of ammonites from the Ceratite formation, referred them very doubtfully to the Paleozoic, because they were supposed to have come from the Productus limestone. C. L. Griesbach[1] who first described the fauna of the *Otoceras* beds of India, referred them to the Lower Trias, in which he has been followed by Wilhelm Waagen[2] and Carl Diener.[3] These writers consider the lower part of the Ceratite formation to be younger than any known Permian, and older than any fauna described from the European Trias, but they regard the affinities of the species as closer to known Mesozoic types, and the beds were considered as homotaxial with the lower part of the Werfen sandstone, the base of the Trias in the Mediterranean region. Now since this part of the Mediterranean section is barren of fossils, this correlation is based entirely on the stratigraphic position of the Ceratite formation.

C. Diener[4], in describing the fauna of the *Proptychites* beds of Ussuri Bay in eastern Siberia, correlated them with the *Otoceras* beds of India, because of the occurrence of several species common to the two regions. It is, therefore, evident that while the correlation of the Ceratite formation of India with the *Proptychites* beds of Siberia and the *Meekoceras* beds of western America may be accepted as correct, the final determination of the age of these beds depends entirely on a comparison with the type of the Lower Trias, the Buntsandstone of Germany, and the Werfen beds of the Alps.

In spite of the weakness of this argument, the Ceratite formation of India has until recently gone unquestioned as the type of the strictly marine equivalent of the Lower Trias, and all correlations of the marine beds have been made by comparison with it. During the last year F. Noetling,[1] paleontologist of the Geological Survey of India, has startled geologists in their fancied security, by the statement, based on his later investigations, that the *Otoceras* beds of India belong to the upper Permian, and are older than the Werfen beds of the Alps. As they lie conformably upon the upper Productus limestone, they represent, according to Noetling, strata of which the equivalents are lacking in the European section. Accordingly he proposes to call the entire Ceratite formation upper Permian, and as a name for the stage he proposes the term Bactrian. If this should prove to be correct it would throw the Ceratite formation of India, the *Proptychites* beds of Siberia, and the *Meekoceras* beds of Idaho and California into the upper Permian.

---

[1] Records Geol. Surv. of India, Vol XIII, 1880. Paleontological Notes on the Lower Trias of the Himalayas, p. 94.

[2] Mem. Geol. Surv. India, Pal. Indica, Ser. XIII. Salt Range Fossils, Vol. II. Fossils from the Ceratite Formation.

[3] *Ibid.*, Ser. XV. Himalayan Fossils, Vol. II, Part I. Cephalopoda of the Lower Trias.

[4] Mem. Com. Geol. St. Petersbourg, Vol. XIV, No. 3. Triadische Cephalopodenfaunen der Ostsiberischen Küstenprovinz.

A. von Kraft,[2] also of the Geological Survey of India, agrees with Noetling, but only as to the Permian age of the *Otoceras* beds; the upper part of the series where *Meekoceras* and *Flemingites* are so abundant he regards as certainly of lower Triassic age. He says that *Medlicottia dalailamae* Diener of the *Otoceras* beds is identical with *M. wynnei* Waagen of the upper Productus limestone, and that *Cyclolobus oldhami* Waagen and *Xenaspis carbonaria* Waagen, which in the Salt Range occur in the middle Productus limestone, in the Himalayas occur in the Kuling Productus shales only twenty or thirty feet below the *Otoceras* beds. This would make the bottom of the *Otoceras* beds (the lower Ceratite limestone) the equivalent of the upper Productus limestone of the Permian. This argument, however, might work both ways, for it would just as well prove that the upper Productus limestone belonged to the base of the Trias, since in any case the division line must be arbitrary. Nor would the finding of *Productus* itself in the *Otoceras* beds prove them to be

---

[1] Geol. Surv. of India, General Rept. for 1899 (1900). Notes on the Relationship between the Productus Limestone and the Ceratite Formation of the Salt Range, and Neues Jahrbuch für Min. Geol. und Pal., 1900. Bd. I, p. 139, Ueber die Auffindung von Otoceras sp. in der Salt Range.

[2] Centralblatt für Min. Geol. und Pal. Bd. II, 1901, p. 275, Ueber das Permische Alter der Otoceras-Stufe des Himalyas.

Paleozoic, for if *Otoceras*, *Medlicottia*, *Xenodiscus*, and *Xenaspis* can range into the Mesozoic, there is no known reason why *Productus* should not have done so. Indeed, *Xenaspis* and *Xenodiscus* range up into the Middle Trias, associated with faunas characteristic of the Muschelkalk.

C. Diener[1] meets Noetling's argument by stating that if the Ceratite formation of India is not of Lower Triassic age, then we have nowhere in the world a strictly marine equivalent of the Werfen beds, and that we have the anomaly of Middle Triassic beds lying conformably on Permian. He shows that the marine Permian of the Alps, which lies below the Werfen beds, has not the fauna of the *Otoceras* beds, but one analogous to that of the *Productus* limestone. Diener admits that the *Otoceras* horizon is older than the fossilferous portion of the Werfen beds, but thinks that the rule of priority of reference must be followed, where there are no paleontologic grounds against it and many for it. He also cites a recent paper by A. Bittner[2] to show that there is found in the *Proptychites* beds of Ussuri a typical pelecypod and brachiopod fauna of Werfen character; it must be admitted, however, that this fauna was not found with the ammonites, and might belong considerably above them.

The most direct comparison with the European Trias has been made by Lukas Waagen,[3] who shows that in the Ceratite marls and the Ceratite sandstone of India he has identified a number of pelecypods identical with forms characteristic of middle and upper Werfen beds of the Alps. This leaves the question about as A. von Kraft stated it. The Ceratite formation, from the Ceratite marls up, certainly belongs to the Lower Trias, since the Werfen beds are the type, while the *Otoceras* beds of the Himalayas, or their equivalent, the lower Ceratite limestone, may belong to the upper Permian. But the fauna of the lower Ceratite limestone and that of the Ceratite marls are so similar that a separation of the two is out of the question, and even the genus *Otoceras* is found in the latter. Now, since these doubtful beds are younger than any accepted Permian, and older than any authentic Trias, they might with equal propriety be assigned to either, and we shall have to extend one or the other system to include them. The question will have to be decided either by paleontologic relationship, or by priority of reference. The *Otoceras* beds contain *Meekoceras*, *Proptychites*, *Ophiceras*, and several other ammonite genera that have never been found in the Paleozoic; they contain also *Medlicottia* and *Otoceras* that are more characteristic of Upper Permian; but they lack the Productidae and Orthidae that characterize the Permian formation. Thus the paleontologic evidence is about equal in favor of a reference to either Paleozoic or Mesozoic. But the geologists that described the fauna of the doubtful beds have almost unanimously referred them to the Lower Trias, and this must be the final verdict.

---

[1] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 1, "Ueber die Grenze des Perm- und Triassystems, etc."

[2] Mém. Com. Geol. St. Petersbourg, Vol. VII, 1899, "Verstein. aus den Trias-Ablagerungen des Süd-Ussuri Gebietes in der Ostsibirischen Küstenprovinz.

[3] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 285.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite marls and the lower part of the Ceratite sandstone of India, with most of the genera in common, and several species that seem to be identical. And although the writer has searched carefully for *Otoceras* in both places, no trace either of this genus or of *Medlicottia* was found. It seems likely, then, that even if the bottom of the Ceratite formation should be cut off from the Trias and assigned to the Permian, this change would not affect the nomenclature of our American formations that are now considered as the bottom of the Mesozoic series, and the *Meekoceras* beds will stand as the type of the marine Lower Trias, where White and Hyatt placed them in 1879. The real transition from Paleozoic to Mesozoic must be sought in the conformable series below the *Meekoceras* beds, and above the *Fusulina* limestone.

JAMES PERRIN SMITH.

STANFORD UNIVERSITY,
California.

STUDIES FOR STUDENTS

THE CONSTITUENTS OF METEORITES. II

Glass.—This is an abundant constituent of the stone meteorites, few if any being entirely without it. It is variously distributed, occurring now as vein matter, now scattered through the substance of chondri, now enclosed in the substance of a single mineral, and now enclosing various minerals.

In the Parnallee, Mezo-Madaras, Chassigny, Farmington and a few other meteorites it has been described as forming a network in which the other minerals are imbedded. Its ocurrence in this manner is rare, however, it playing usually a merely accessory part. It chiefly abounds as inclusions and intergrowths in chrysolite, taking in this association a great variety of forms. Other minerals too, frequently have inclusions of glass. It may occur in fragments of considerable size or the particles may be of a dustlike minuteness.

Its abundance in chondri has already been mentioned. By all these occurrences a rapid crystallization or cooling of the meteorite substance is strongly indicated. Like the glass of terrestrial lavas it seems to be the result of cooling so rapid as to prevent differentiation and orderly crystallization of the magma. The especial abundance of glass in meteoritic chrysolite, the least fusible and therefore the earliest cooling ingredient further favors this conclusion.

The prevailing color of the glass of meteorites is brown. Much is however colorless and some occurs so dark as to be opaque. Grayish and greenish tones occur but are rare.

Chromite.—Nearly all stone meteorites give on analysis a small percentage of chromium which is usually considered as being present in the form of chromite, FeO, Cr_2O_3. The mineral is not so abundant in the iron and iron-stone meteorites but has been detected in several and in the Coahuila irons occurs in nodules of considerable size ($17^{mm} \times 12^{mm}$).

It is identical with terrestrial chromite in composition and properties. Not being acted upon by acids, it may be readily distinguished from daubréelite. It is generally non-magnetic, but sometimes feebly magnetic. Where crystals occur they are commonly octahedrons, sometimes modified by other forms.

Amorphous carbon.—Meteorites of the group known as carbonaceous meteorites, as well as some others, are permeated by a dull-black pulverulent coloring matter which is usually left as a residue on treatment of the meteorite with acid. This residue sometimes amounts to from 2–4.5 per cent. of the mass.

A residue similar in character though smaller in amount is likewise found after dissolving many of the iron meteorites. These residues on being heated in air glow, usually become lighter in color and give off carbon dioxide. They must therefore be considered practically pure carbon.

Berzelius and Wöhler believed this carbon to have originated so far as the carbonaceous meteorites are concerned, from the decomposition of the hydrocarbons of the latter. In this respect they regarded it analogous to terrestrial humus, though of very different origin. Smith considered it similar in origin to the graphite of iron meteorites and Weinschenk believes it similar to one of the forms of carbon produced in the making of cast iron. No indications that it had an organic origin have ever been discovered.

Diamond.—The existence of diamonds has been definitely proven in only two meteorites, those of Cañon Diablo and Nowo-Urei. Diamonds have, however, also been reported from the irons of Magura and Smithville and the stone of Carcote. The diamonds of the Cañon Diablo meteorites have been most studied. Here they are found as minute particles or dust left as a residue after dissolving the meteorite in acid. The particles rarely exceed $\frac{1}{2}^{mm}$ in diameter. They are usually brown to black in color but sometimes are colorless and transparent. They accompany graphite, amorphous carbon and often troilite and schreibersite. They have a tendency to gather in little clefts or hollows and are not regularly distributed. Their character as diamond is proven chiefly by their hardness, but analyses and a study of their behavior in polarized light give confirmatory results. Huntington found some also which showed crystal forms of diamonds. The occurrence of diamonds in meteorites suggests interesting analogies with their terrestrial occurrence. Knop and Daubrée call attention to the fact that the peridotic rocks in which terrestrial diamonds occur are the rocks most nearly allied in composition to meteorites. In the iron meteorites, as Moissan has proven satisfactorily by experiment, diamond is to be considered a form in which, under certain conditions of heat and pressure, carbon separates. Moissan obtained diamonds by heating to a high temperature iron saturated with carbon and allowing it to cool under pressure. The carbon was then found to exist in three forms, graphite, foliated carbon, and a diamond powder which latter corresponded to that obtained from the Cañon Diablo meteorites.

A form of carbon resembling graphite but differing in having a hardness of 2.5 and being isometric in crystallization, has been noted in the Magura, Cosby's Creek, Youndegin, Toluca and a few other iron meteorites. It was first discovered by Fletcher, who considered it a distinct species and gave it the name cliftonite. Other authorities, however, regard cliftonite as a pseudomorph after diamond, since its crystals closely resemble those of diamond in form.

Daubréelite.—This mineral is an iron-chromium sulphide peculiar to meteorites. Its composition is $Fe\,S, Cr_2\,S_3$. It is found in nearly all the cubic iron meteorites and has also been identified in the irons of Toluca, Nelson county, Cranbourne, Cañon Diablo and others. It has never been found in stone meteorites. It usually accompanies troilite, either bordering nodules or crossing them in veins. Sometimes, however, it occurs as thin plates or grains. It is black in color, has a black streak, is of metallic luster, brittle and not magnetic. It is infusible before the blowpipe and becomes magnetic in the reducing flame. It is not attacked by hot or cold hydrochloric acid, but is completely dissolved by nitric acid without the separation of free sulphur. This solubility distinguishes it from chromite. Its system of crystallization is not known though it exhibits rectangular and triangular partings which indicate one of the systems of high symmetry. Meunier obtained the mineral artificially by treating an alloy of iron and chromium at a red heat with hydrogen sulphide.

Tridymite.—This mineral has been positively identified in only one meteorite (Steinbach), but it probably also occurs in the Vaca Muerta and Crab Orchard Mountains meteorites. These are all ironstone meteorites. In the Steinbach meteorite it forms from 8.5 to 33 per cent. of the non-metallic constituents and occurs intergrown with bronzite.

Maskelyne, who first described the mineral, considered it on account of its optically biaxial character a new orthorhombic form of silica and gave it the name of asmanite. Since tridymite is now known, however, to exhibit biaxial characters and the minerals agree in most other respects, they are generally considered identical.

Tridymite occurs in meteorites in the form of rounded grains or plates, some of which reach a length of 3^{mm}. They are colorless to white to rusty brown in color.

Well developed crystals are rare but from facets on rounded grains a total of twelve forms has been determined.

Analyses show a composition of practically pure silica, with iron oxide and magnesia present as impurities.

Lawrencite.—This is a solid ferrous chloride which has been described from the iron meteorites of Tazewell, Smith Mountain, and Laurens county. Formula $Fe\,Cl_2$. Color green to brown. While described in the solid form from only the few meteorites mentioned, the presence of lawrencite in many other iron meteorites is generally believed to be indicated by the greenish drops which exude on their surfaces. These drops are ferric chloride or mixtures of ferric and nickel chloride, while occasionally pure nickel chloride occurs.

The meteorites from which ferric chloride exudes disintegrate with especial rapidity. Such meteorites are often known as "sweating" meteorites. The "sweating" is rarely noted in ironstone or stone meteorites, but the small percentage of chlorine found in the analysis of many of these meteorites is usually referred to lawrencite. Some authorities hold that the substance is not an original constituent of any meteorite, but is wholly of terrestrial origin. This is not the general opinion however.

Ferrous chloride has been noted among the sublimation products at Vesuvius and is reported as having been found in the terrestrial nickel-iron of Ovifak.

Magnetite.— Several stone or ironstone meteorites have been found to contain black, magnetic grains which dissolve in hydrochloric acid without effervescence to form a yellow solution.

In the meteorites of Shergotty and Doña Inez these are sufficiently abundant to form an essential constituent. They constitute 4.57 per cent. of the Shergotty meteorite. Similar grains occur as inclusions in maskelynite, pyroxene, and chrysolite in the above and other meteorites. They are regarded as magnetite.

No well marked crystals of meteoritic magnetite have as yet been described.

Magnetite has been reported as a constituent of several iron meteorites though only one analysis has been made, that of Meunier of magnetite from the crust of one of the Toluca irons. The composition of this agreed with that of terrestrial magnetite. Several other iron meteorites show magnetite in their crust. Here, however, the magnetite may have originated from the oxidation of the iron of the mass since its arrival upon the earth.

Magnetic spherules have been dredged up from ocean depths, which Murray and Renard regard as particles of meteoric iron oxidized to magnetite since their arrival upon the earth.

Oldhamite.—This is a simple calcium sulphide with the formula $Ca\ S_2$. Grains of it were found by Maskelyne embedded in the enstatite or augite of the Bustee meteorite. It is light brown in color and transparent when pure. Hardness 4, specific gravity 2.58. It is isotropic and has equal cleavage in three directions, hence is doubtless isometric. In the Bustee meteorite it occurs in rounded grains, coated with gypsum through alteration.

Certain yellow grains found in the Bishopville meteorite were also considered by Maskelyne to be this mineral. Aside from these two occurrences it has not been positively identified in any other meteorite.

Calcium sulphide resembling oldhamite was obtained by Maskelyne by heating caustic lime in a glass tube, first with hydrogen, then with hydrogen sulphide. Vogt has noted a similar compound formed in furnace slags.

It has not been found as a terrestrial mineral.

On dissolving the oldhamite of the Bustee meteorite, Maskelyne found a residue constituting about 0.3 per cent. of the weight of the former, consisting of yellow octahedrons of microscopic size. These were found to be unaffected by acids or oxygen, while qualitative tests indicated sulphur, calcium, and titanium or zirconium. Maskelyne regarded the mineral therefore an oxysulphide of calcium and titanium and gave it the name osbornite. No other occurrence of the mineral is known.

Hydrocarbons.—The hydrocarbons found in meteorites may be divided, following Cohen,[1] into three classes: (*a*) compounds of carbon and hydrogen; (*b*) compounds of carbon, hydrogen and sulphur; and (*c*) compounds of carbon, hydrogen and oxygen. They especially characterize meteorites of the class known as carbonaceous, which includes seven or eight distinct falls of meteorites of black color, low specific gravity and containing a sensible amount of carbon. They have been obtained from some other meteorites however, such as those of Collescipoli and Goalpara. The hydrocarbons of the first class are obtained by treating these meteorites with alcohol or ether. They are resinous or waxlike bodies which completely volatilize on the application of heat. When heated in a closed tube the resinous substances first fuse, then are decomposed to form amorphous carbon and an oil hava bituminous or fatty odor. Such substances were considered by Wöhler similar to the mineral wax ozocerite and by Shepard they were designated meteoritic petroleum. Friedheim states that a substance extracted by him from the meteorite of Nagaya by means of ether had a bituminous odor, volatilized at 200° and resembled a product of distillation of brown coal. A similar substance extracted by Roscoe from the meteorite of Alais was found to have a composition corresponding nearly to the formula $C H_{2n}$.

---

[1] Meteoritenkunde. Heft. I, p. 159.

Hydrocarbons of the second class were obtained by Smith by treating the graphite of iron meteorites and some carbonaceous meteorites with ether. These compounds were fusible and volatile. He regarded them as having the general composition $C_4H_{12}S_5$. He obtained similar products by treating cast iron with ether or petroleum as did also Berthelot by the action of ether on sulphur or iron sulphide in the presence of oxygen.

Hydrocarbons of the third class have been obtained from the meteorites of Orgueil and Hessle. The Orgueil extract resembles peat, humus or lignite in its composition and properties. That from Hessle has approximately the composition $n\,C_9H_8O_2$.

The above mentioned facts make it clear that a number of meteorites contain products of an easily destructible, volatile, and combustible character which resemble terrestrial bitumens, petroleum or oxygenated hydrocarbons. The quantity of these products is relatively small, being less than 1 per cent. in the majority of meteorites in which they occur. Yet that they occur at all is significant. While some have urged that these products might have arisen from the union of their elements in the terrestrial atmosphere there seems little reason for doubting their pre-terrestrial origin. There is no evidence that life had anything to do with their origin. We must conclude then that they were formed in an inorganic way by a union of their elements. The conclusion at once suggests the possibility that terrestrial hydrocarbons need not always be referred to an organic origin, but may have been formed in a purely inorganic way.

The occurrence of hydrocarbons in meteorites further shows that such meteorites could not have been subjected to any high degree of heat subsequent at least to the formation of these compounds, and that the heating of meteorites during their fall to the earth has in many cases been only superficial.

The trails of light, sometimes enduring several minutes, observed following in the wake of some meteors may perhaps indicate the presence of carbonaceous matter in those bodies. The stone shower which took place at Hessle was accompanied by luminous effects and with the stones fell a brownish-black powder which contained 71 per cent. carbonaceous matter. Other carbonaceous meteorites have fallen, however, without exhibiting any marked luminous phenomena.

Other compounds.— Besides the above well-determined compounds a number of others have been reported at different times which are (1) present in insignificant amount or (2) their occurrence has not been confirmed, or (3) they may be of terrestrial origin. Among these a few may be mentioned: *Quartz.* This mineral, as is well known, is remarkable for its absence from meteorites. Yet it doubtless does occur in minute grains in a number of iron meteorites, since on dissolving them a residue is left, the grains of which possess the properties of quartz. Its occurrence in any stone or ironstone meteorite has never yet been established. *Pyrite.* This mineral has been reported a number of times, but sufficient proof to establish its identity has not been given. Von Siemaschko reported from the meteorite of Ochansk a brass-yellow pentagonal dodecahedron of which, however, he gave no measurements. Daubrée found in the meteorite of Senhadja, bronze-yellow grains insoluble in hydrochloric acid, soluble in aquaregia and altering easily to iron sulphate. While these and other observations suggest pyrite they are not conclusive. *Salts soluble in water.* Several of the carbonaceous meteorites as well as one or two others give on evaporation of the water extract a residue of soluble salts reaching in quantity in one case as high as 10 per cent. of the mass. These salts include nickel, calcium, magnesium, potassium, sodium and ammonium sulphates and chlorides.

Since the meteorites in which they occur are very porous in character and show other signs of alteration these compounds are usually considered to be formed by terrestrial modification of the meteorite and not to exist as original constituents. Daubrée, however, gives good reasons for regarding the sodium chloride which he found in the Lancé meteorite an original constituent. These reasons are that the meteorite had lain only three days in a clayey bed before it was picked up and no salt is known to have come near it. *Breunnerite.* This mineral was found in the meteorite of Orgueil occurring in the form of little transparent crystals. The identity of the mineral was established both by qualitative tests and by goniometric measurements. It has been suggested that it was of secondary origin. As it was found well within the interior of some masses, this, however, hardly seems likely. This is the only carbonate known from meteorites.

A number of other minerals have been reported from meteorites without sufficient grounds, according to the writer's view, to support the conclusion. Cohen considers them doubtful while Meunier accepts most of them. These are: *Apatite*, *iolite*, *wollastonite*, *titanite*, *garnet*, *vesuvianite*, *mica*, *aragonite*, *leucite*, *cassiterite*, *hornblende*, *anthophyllite and orthoclase*.

Mineral aggregates.—The different aggregates which the compounds above described form in different meteorites are too various to be recorded here in detail. For an account of these, reference should be made to the elaborate classifications of Meunier,[1] Brezina[2] or Wülfing.[3]

A few general observations may be made here, however, following the lines of the classification given by Wülfing. The iron-meteorites, as already indicated, are made up chiefly of nickel-iron, with schreibersite, troilite, daubréelite and a few other minerals occurring as accessories.

---

[1] Revision des Pierres Météoriques. Paris, 1897.

[2] Annalen des k. k. Naturhistorischen Hofmuseums. Bd. X, Heft 3 u. 4. Vienna, 1896.

[3] Die Meteoriten in Sammlungen. Tübingen, 1897, pp. 447–460.

Of the ironstone meteorites the largest quantity are of the so-called pallasites, formed chiefly of chrysolite and nickel iron. Nine falls of this group are known, having a weight of 1742 kilograms. In the group known as siderophyrs, represented by one fall (82 kilos), of meteoritic matter, bronzite and tridymite are associated with the nickel-iron. In the group of mesosiderites (grahamites) represented by ten falls (483 kilos), of meteoritic matter, the nickel-iron is accompanied by chrysolite, bronzite, plagioclase, and augite. In the group lodranite, composed of one fall with a weight of 1 kilo, chrysolite and bronzite are associated with nickel-iron.

Passing to the stone meteorites the following groups and weights may be noted:

A. Stones rich in calcium and magnesium and containing little or no nickel-iron.

1. Angrite. Chiefly augite. One fall, weight 0.4^{kg}.
2. Eukrite. Augite and anorthite. Four falls, weight 91^{kg}.
3. Shergottite. Augite and maskelynite. One fall, weight 5^{kg}.
4. Howardite. Augite, anorthite, bronzite, and chrysolite. Ten falls, weight 5^{kg}.

B. Stones rich in magnesia and containing little or no nickel-iron.

1. Bustite. Diopside and bronzite. Two falls, weight 1.7^{kg}.
2. Chassignite. Chiefly chrysolite. One fall, weight 0.9^{kg}.
3. Chladnite. Chiefly orthorhombic pyroxene. Four falls, weight 9^{kg}.
4. Amphoterite. Chiefly chrysolite and bronzite. Three falls, weight 40^{kg}.

C. Stones rich in magnesia and consisting essentially of chrysolite, bronzite, nickel-iron, and iron sulphide. Here belong the great majority of stone meteorites.

A comparison of the constituents as above described with those of the crust of the earth brings to view some interesting similarities and contrasts. Under *similarities* may be noted the fact that the elements of meteorites are the same as those of the earth and that they unite according to the same chemical and physical laws. No new element has been discovered in meteorites and the chemical compounds of meteorites similar to those of the earth agree even to the details of their crystal form.

Under *contrasts* it may be noted that two agents which have affected largely the composition of the crust of the earth have been lacking either wholly or in part in the formation of meteorites. These agents are water and oxygen. The lack of water is proved by the fresh and unaltered character of the minerals found in meteorites and the absence of all hydrous minerals. Thus the chrysolite of meteorites is never found serpentinized nor are the pyroxenes changed to chlorite nor the feldspar to kaolin.

Further, zeolites, micas, epidote, tourmaline and all other minerals in the formation of which water and water vapor play a part are entirely lacking from meteorites.

Similarity, oxygen, at least in excess, is lacking from the constituents of meteorites. Such substances as nickel-iron, schreibersite, and lawrencite, which make up so large a part of the composition of meteorites would rapidly have been oxydized had they been exposed to the action of oxygen as it occurs upon the earth. The silicates of meteorites are however oxydized compounds which show that oxygen is present to some degree in space.

Again, as noted by Cohen,[1] the important rock-forming minerals of the crust of the earth are either lacking or play an insignificant part in the formation of meteorites. Such are quartz, orthoclase, the acid plagioclases, the micas, the amphiboles, leucite, and nepheline. Vice versa, the chief mineral constitutents of meteorites occur in but insignificant amount upon the earth. Such are nickel-iron, the orthorhombic pyroxenes and chrysolite, while such compounds as schreibersite, cohenite, lawrencite, oldhamite, daubréelite and troilite rarely or never occur terrestrially. Looked at quantitatively then it may be said that terrestrial rocks abound in free silica, lime, alumina, and alkalies, while meteorites abound in iron, nickel and magnesia. Whether these quantitative differences would be maintained if the constitution of the earth as a whole could be compared with that of meteorites, is, as hinted at the beginning, doubtful.

OLIVER C. FARRINGTON.

---

[1] Op. cit., p. 323.

Among the innumerable phases of the great calamity which has fallen upon our country and the world in the tragic death of PRESIDENT McKINLEY, the loss of a generous friend of science is by no means the least. The prosperity of the scientific bureaus under his administration has been as marked in improved organization and in method as in extension and in generous patronage, and the establishment of a new bureau in the interest of scientific and commercial precision is a laudable feature of special moment.

EDITORIAL

IN December, 1898, Mr. G. K. Gilbert presented to the Geological Society of America a paper upon ripple-marks and cross-bedding in which he undertakes to explain the large ripples of the Medina formation.[1] Mr. Gilbert became satisfied that these ripples differ "in no respect except size from the familiar ripple-mark of the bathing beach and the museum slab." In order to account for the size of some of the large ripples upon this theory he has inferred that the waves producing them were sixty feet high and made in "a large ocean."

In the July number of the *American Geologist*, Professor H. L. Fairchild objects to the deep ocean theory of the origin of these ripples, and brings evidence to show that they are beach structures.[2]

Without going into the details of either of the articles mentioned the present writer wishes to call attention in this connection to a paper upon the origin of beach cusps published in this JOURNAL (September–October, 1900, Vol. VIII, pp. 481–484), and to suggest that the explanation of the giant ripples spoken of by Gilbert and Fairchild is to be found in the seaward extension of beach cusps. The beach cusps are from sixty to eighty feet apart, from a few inches to three feet in vertical height and extend oceanward in approximately parallel lines. They are formed by the interference of two sets of waves of translation, and are therefore to be looked for not only on the beach where they appear at the water's edge, but as far out as the waves drag upon the sea bottom, and always pointing away from the shore. This theory appears to account readily for all the phenomena observed in connection with the ripples in the Medina without doing violence to the theory of the shallow water origin of those beds.

---

[1] Ripple-marks and Cross-bedding, by GROVE KARL GILBERT. Bull. Geol. Soc. Amer. Vol. X, pp. 135–140.

[2] Beach Structures in Medina Sandstone, by H. L. FAIRCHILD. Amer. Geologist, Vol. XXVIII, pp. 9–14.

J. C. BRANNER.

THE experiment of holding the summer meeting of the American Association for the Advancement of Science as far west as Denver may be regarded as a success. The attendance compared favorably with what has previously been realized at several meetings in the interior, though for obvious reasons it was less than the attendance at meetings held in the more populous and accessible centers of the East. The papers and discussions, so far as one could judge from listening to those of a single section and from current opinion, also compared favorably with those of average meetings. There was less diversion from the specific purposes of the association by formal social functions which were few, and there was correspondingly greater real social intercourse between fellow scientists, because the intersessional intervals were more largely left free for this, a most laudable feature. The provisions for scientific excursions, at least in geologic lines, were notably more ample than usual and were arranged for the afternoons of the regular session, the morning sessions being extended to make this possible. The facilities for general and varied excursions at the close of the formal sessions were exceptionally generous. Only one feature of the general appointments and of the environment needs to be singled out for adverse comment, and that was the dreary silliness of the Denver press which, apparently recognizing its limitations in reporting appreciatively and intelligently the real scientific news, tried to make up for its inabilities by stale witticisms and coarse cartoons, interspersed with extravagant personal laudations of "the-greatest-scientist-on-earth" type. A few subjects relating to the economic interests of the region and to popular themes were, however, well reported.

The general addresses were excellent; that of retiring-President Woodward was an incisive and discriminating discussion of the progress of science, graced with an artistic marshaling of lights and shadows as wholesome as it was skilful; that of Vice-President Van Hise on the philosophy of ore deposition was clear, strong and effective, and especially laudable, as a popular address in a mining region, for its unhesitating advocacy of the unpalatable as well as the acceptable phases of his doctrine.

Previous to the meeting a ten-day excursion of geologists was planned by Professors Van Hise and Emmons and carried out in a most admirable manner. The selection of routes and places from among the phenomenal possibilities of Colorado certainly made no small demands upon the knowledge and discretion of those in charge, but no whisper of a possible improvement was heard. The climax of interest was reached in the San Juan Mountains, where the exemplification of many and varied phases of geological phenomena from the Archean to the Pleistocene is marvelously impressive. The aid rendered by prominent citizens at various points visited and the generous hospitality extended to the party were beyond all praise. It would be a delight to acknowledge our obligations in special and individual terms, if, beginning with the exceptional courtesies of Walsh, Lay, and Freeland, it were possible to find an end of the list. About two dozen geologists participated.

The four geological sessions were crowded with papers well distributed over the various departments of geology and embodying much of exceptional interest and value. The papers read before the Geological Society of America, presented on the first morning, were as follows: "Account of the Geological Excursion," C. R. Van Hise; "Junction of the Lake Superior Sandstone and the Keweenawan Traps in Wisconsin," U. S. Grant; "Hydrographic History in South Dakota," J. E. Todd; "The Still Rivers of Western Connecticut," W. H. Hobbs; "Geology of the Northeast Coast of Brazil," John C. Branner; "Classification of the Geological Formations of Tennessee," James M. Safford; "Horizons of Phosphate Rock in Tennessee," James M. Safford.

The following papers were presented before Section E:

"The Effect of Diurnal Heat on Glacial Activity," J. F. Todd; "On Extra Terrestrial Stresses," E. Haworth; "On Stoping as a Factor in the Formation of Terraces," T. C. Chamberlin; "On Campodus, Helicoprion, Acanthus and other Paleozoic Sharks," Charles R. Eastman; "The Oscillations of the Coast Ranges of California," A. C. Lawson; "Some Features of the Geology of Golden, Colorado," H. B. Patton; "The Geological Occurrence of Oil in Colorado," A. Lakes; "Report on Some Studies Relative to Primal Questions in Geology," T. C. Chamberlin; "A Plea for Greater Simplicity in the Language of Science," T. A. Rickard; "Sandstone Intrusions near Santa Cruz, California," J. F. Newsome and J. C. Branner; "On the Pleistocene Deposits of Iowa," Samuel Calvin; "Problems of the Quaternary Deposits of the South Platte Valley," George L. Cannon; "Physiography of the Boston Mountains, Arkansas," A. H. Purdue; "Some Problems of the Dakota Artesian System," James E. Todd; "A Quantitative Study of Variation in the Fossil Brachiopod Platystrophia biforta, Schl.," E. R. Cumings and A. V. Mauck; "Interpretation of Some Drainage Changes in Southwestern Ohio," W. G. Tight; "The Minerals and Mineral Localities of Texas," F. W. Simonds; "The Minerals Associated with Copper in Southeastern Arizona and Southwestern New Mexico," G. H. Stone; "The Extinct Glaziers of New Mexico and Arizona," G. H. Stone; "Note on Certain Copper Minerals," A. N. Winchell; "The Areal Geology of the Castle Rock Region," W. T. Lee. The officers of the section were: C. R. Van Hise, vice president, and H. B. Patton, secretary. Those elected for the ensuing year are: O. A. Derby, of San Paulo, Brazil, vice president; and F. P. Gulliver, of Southboro, Mass., secretary.

C.

REVIEWS

THREE PHASES OF MODERN PALEONTOLOGY

I. *Uintacrinus: Its Structure and Relations.* By FRANK SPRINGER. (Mem. Mus. Comp. Zoöl., Vol. XXV, pp. 1–90, 8 pls., Cambridge, 1901.)

II. *Oriskany Fauna of Becraft Mountain.* By JOHN M. CLARKE. (Mem. New York State Mus., Vol. III, No. 3, 128 pp., 9 pls., Albany, 1900.)

III. *Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field.* By DAVID WHITE. (U. S. Geol. Surv., Twentieth Ann. Rept., Part II, pp. 749–930, 13 pls., Washington, 1901.)

Three notable contributions to our knowledge of fossil organisms have lately appeared from the hands of the printer. They are notable as making distinct advancements in paleontology. They are notable as typifying the three distinct phases into which the science relating to ancient life has finally resolved itself. They are notable as model works of their kind, each representing the general subject from a very different viewpoint, and hence show very diverse modes of treatment and the very diverse character of paleontological inquiry of today.

1. The crinoids have long been an attractive theme to geologists. Ever since the discovery by Marsh, in 1870, of the remarkable Cretaceous crinoid afterward called Uintacrinus, great interest has been taken by paleontologists in each new accession. Grinnell, Meek, Willison & Hill, and Logan, in this country, and in Europe, Schlüter and Bather, have described carefully the known material. It has remained for Mr. Springer, so long intimately associated with the lamented Wachsmuth, to give us a magnificent monograph on the subject, including a large amount of new information derived from rich, lately discovered material. And this after one would naturally think that about all that it was possible to say had been said.

The special charm and value in this work is the strictly morphological character that it presents. In this respect it fully keeps up the same high standard of excellence that made the *North American Crinoidea Camerata* of Wachsmuth & Springer so acceptable to all students of fossil organisms.

Unusual interest centers in the composition of the base of Uintacrinus. A feature that has long been regarded as fundamental in the separation of the larger taxonomic groups is here found in one and the same species. "Considering the apparent identity of these forms in every other point of structure, coupled with their mode of occurrence and association, I do not see how such association [as made by Mr. Bather] can possibly be made in this case. We therefore have apparently to deal with a case of individual variation as to this supposed primitive character, within the limits of a species. That is to say, in this species, living in the same locality, having the same environment, floating in the same mass, certain individuals matured to represent one stage of larval development, *i. e.*, with infrabasals; and others in another stage, *i. e.*, with basals only.

In short, there are the two supposed distinct types, Monocyclica and Dicyclica, occurring in both young and adult of one and the same species. It will not do to say that the species is dicyclic, but in certain individuals the infrabasals are not developed, or are hidden by the centrale, or have disappeared by atrophy, If this were so, the centrale ought to be interradial in both cases; whereas, as already shown, its orientation is reversed from one to the other, precisely as in the typical monocyclic and dicyclic forms.

Such a condition is believed to be unique among the crinoids. The bearing upon certain recently proposed classifications of the crinoids is also important. Bather and Jaekel have both severely criticised Wachsmuth & Springer's classification and have erected schemes that are "sought by the modern biologist."

"There is no doubt," says Mr. Springer, "that each author who undertakes to express his ideas of descent in a new scheme of classification does so in the belief that his own structure is a substantial pyramid whose base is firmly established upon the ruins of the top-heavy contrivances of his predecessors. With regard to the crinoids, there have appeared, since our monograph of the Camerata, two elaborate classifications, each avowedly based upon phylogenetic principles, viz., that of Mr. Bather, already mentioned, and one by Dr. Jaekel, whose general researches and great works upon the crinoids of Germany constitute a rich contribution to science. The views of the latter author are to be developed in full detail in his magnificent

"Stammesgeschichte der Pelmatozoen," the first part of which, embracing the Thecoidea and Cystoidea, has just been published. He, likewise, finds fault with Wachsmuth & Springer, because, in his opinion, they have dealt with the morphological conditions as they found them too much from an anatomical standpoint, and have not sufficiently taken into account the import of the modifications due to descent. He finds in the changes in the systematic arrangement of the crinoids made by Wachsmuth & Springer in their successive writings, proof that the right road to the solution of the great questions of classification had not yet been found. We have, therefore, two new and almost simultaneous phylogenetic classifications, by two of the most eminent living authorities, both predicated in part upon the insufficiencies of Wachsmuth & Springer's system, and each believed by its author to be a new and correct reading of the race history of the crinoids. From such sources, and following such a preface, we should not unnaturally expect a brilliant illumination of the road, in search of which their predecessors have floundered in darkness. But to our dismay we find that instead of celebrating a conclusive settlement of these questions, we are only invited to witness fresh controversy. For these new chroniclers do not read their history alike, and their two classifications are about as diametrically and fundamentally opposite as anything could be."

Uintacrinus presents a striking resemblance to the living crinoid Actinometra in the eccentric position of its mouth, the central position of the anus, the absence of any calcified ambulacral skeleton on disk, arms and pinnules, the structure and distribution of the disk ambulacra, the form and proportions of brachials, and distribution of syzygies, the variable size of the anal tube, and the instability of the base.

The systematic position of Uintacrinus will be a matter of controversy for a long time to come. As yet hardly any two authorities agree in placing it in the same position.

Wherever it may belong, and whatever its line of descent, there is no doubt that Uintacrinus is both a protean and convergent form more remarkable than any we have hitherto encountered among the crinoids. Along with great variability in the base and interbrachial regions, it combines:

The interbrachial system and fixed pinnules of the Camerata;

The pliant test of the Flexibilia;

The large visceral cavity of both of these;

The exoclyclic disk and open ambulacara, and the arms, pinnules, and syzygies of Actinometra;

The free-floating character of the Comatulæ;

The dicyclic base of the Dicyclica;

The monocyclic base of the Monocyclica.

A noteworthy feature that should receive special mention in connection with this monograph is the distribution of study material, illustrating the points and structures discussed, to some of the principal museums. It is a feature that could well be imitated by other workers in paleontology. In this way the principal type specimens have been deposited in the Museum of Comparative Zoölogy. A large slab has been placed in the National Museum at Washington; it contains specimens exhibiting most of the characters discussed. A fine series of specimens have also been sent to the British Museum, and to the Royal Museum of Natural History at Berlin, where they will be accessible to European students.

2. As stated by Dr. Clarke, in his prefatory note to the *Oriskany Fauna of Becraft Mountain*, the original purpose of his work was solely to depict the character and composition of the Oriskany fauna of Becraft Mountain, which of itself displays many features of interest. In its progress, however, various questions have arisen which concern the intrinsic value of the fauna and its importance in correlation. Yet without an understanding of the fauna itself it would be impracticable to discuss the latter problems, and for this reason the title of the paper is restricted to the principal argument of the work, to which the discussions of a somewhat broader scope are corollaries.

A fauna which finds its highest development at Becraft Mountain, near Hudson, in Columbia county, N. Y., links together in the character of its species, the calcareous shales and limestones of the Lower Helderberg and the normal Oriskany sandstone.

The interesting bearings of this assemblage of species, its new forms and new associations and its real importance in the correlation of the Lower Devonian are sufficient reason for presenting its characteristics in detail.

A brief account of the stratigraphy of the mountain is given, and also the general New York section as recently revised. Accompanying these is a small geological sketch-map of the Becraft Mountain syncline.

The greater portion of the memoir is devoted to the description of species, which are finely illustrated by nine plates of figures. A table of the vertical range of species occurring in the region is given.

With our present knowledge there are thus 113 recognizable, distinct specific forms in the fauna of the Oriskany at Becraft Mountain, and of these 94 are identifiable with species already known or are clearly new forms peculiar to the fauna. Of the 94, 25 preceded the introduction of the Oriskany sedimentation, having been first described from the fauna of the Helderbergian. In the arenaceous beds of the Oriskany 23 occur; 10 range upward into the faunas of the Upper Helderberg (Ulsterian), but a part of these are restricted to the sandy, lower beds of this formation (Schoharie grit), and others have been noted only in the chert beds of Ontario, Canada, where the intermixture of Oriskany and Onondaga species is well marked and has been recorded by Schuchert. The fauna contains 35 species which so far as known are peculiar to it. On farther analysis of the table, it is evident in some cases that species which range down and upward are restricted to particular groups. Thus the alien trilobites are from the Helderbergian; the gasteropods are exclusively Oriskany; while the alien lamellibranchs are mostly Helderbergian. But the leading factor of the fauna, the brachiopod, has its derivation as freely from below as in the Oriskany invasion.

The faunal values of the different species are then summed up.

Concerning the nature of the Oriskany fauna of New York, the author says:

> The fauna of the calcareous Oriskany is in no sense a mixed assemblage, or an intermingling of faunas of adjacent provinces. The sequence of life has continued without interruption from the Helderbergian (Kingston beds) into the sediments of the Oriskany and Onondaga limestone.
>
> It is extremely probable that important variations from the fauna of the Catskill shaly (New Scotland) limestone had already made their appearance in the Becraft limestone, and that we first become acquainted with some of these in the study of the calcareous Oriskany. No proof therefore could be adduced more emphatically confirmatory of the intimate faunal relations of the Helderbergian with the Oriskany fauna and its successors than the facts brought forward in this paper.
>
> The fauna discussed is that of the calcareous facies of the Oriskany formation. The sedimentary deposits of this and the neighboring sections were essentially limestones notwithstanding the silicious content, whether diffused through the mass or segregated as cherty secondary product. In the earlier presentation of this fauna it was regarded as of lower Oriskany horizon on account of the presence of many Helderbergian species, but we believe it will be more correctly construed as the representative of the proper and normal Oriskany fauna, the true fauna of this time-unit inclosed in the sediments of its proper habitat.

A chapter is devoted to discussing the Devonic age of the Helderbergian fauna and the base of the Devonic system in New York.

The fact of the presence of numerous Helderbergian species in the fauna of the Oriskany of Becraft Mountain, as an integral part of that fauna, not a casual intermixture, is sufficient demonstration that the fauna of the Helderbergian became modified in its continued existence by the departure or extinction of certain of its species only. A fair percentage kept the field up to the time of and pending the incursion of species of the early Oriskany. In this way the former became a true and proper part of this new fauna with whose indicial species it coexisted throughout the remainder of its duration. A modification so gradual as to permit such an uninterrupted existence cannot sever the close relation of the one fauna in its entirety to the other. It is therefore a natural corollary from the account given of the Oriskany fauna, to consider briefly the relation of the organic assemblage constituting the typical and normal Helderbergian to the Devonic type of organic life, and that formation in its relation to the Devonic system.

Arguments are adduced from the intrinsic characters of the fauna, from correlation, and from stratigraphy.

3. Of very different nature is Mr. White's work on the plants of the Pennsylvania Coal-measures. The stratigraphical interval which he considers is occupied by the Pottsville formation, Pottsville series, or Pottsville conglomerate. It is described as a series of largely arenaceous beds of variable thickness which in eastern Pennsylvania lies between the Maunch Chunk red shale, or distinctly Lower Carboniferous, and the lower productive Coal-measures, or distinctly Upper Carboniferous.

The investigation was intended to establish three propositions: (1) The exploitation and elaboration from, a stratigraphic standpoint, of the fossil plants of the Pottsville formation in the type region of the southern anthracite coal field; (2) the critical analysis and comparative study of the plant material collected, with a view to the discovery of the existence of any natural paleontological subdivisions, zones, or horizons, and their paleontologic characters, or the species of stratigraphic value; (3) the discovery of the paleontologic limits as differing or as agreeing with the lithologic limits of the type section, and the consequent paleontologic definition of the formation.

The main aim of the investigation is the paleontologic definition of the terrane.

Two other, largely concomitant, results that are either economic or scientific in their nature have also been reached in the process of the elaboration of the fossil plants of the formation in the typical region. The first, of some economic interest, is the correlation of the groups of beds, or of individual coals wrought in disconnected or somewhat isolated portions of the southern anthracite field. The other, which concerns the question of general geological correlation, is the acquisition of data for the determination of the age of the Pottsville formation—*i. e.*, (*a*) the time interval represented by the type section, and (*b*) the equivalents, in a broad sense, of the formation in other basins of this province and in other parts of the world. Incidentally also, through the discovery in the Pottsville of floras already more or less completely known from isolated and uncorrelated terranes in other regions of the United States, the way is opened to the proper reference and correlation of those terranes with the Pottsville, or with portions thereof.

As introductory to the consideration of the plant remains as a means of geological classification there are presented a sketch of the general geological structure of the southern anthracite coal field, a description of the Pottsville formation in the typical locality, the composition of the formation, the coals contained, and their commercial names as guide horizons.

A type paleobotanic section of the Pottsville is then discussed, and the groupings of beds are enumerated. The various species and their observed distribution within the formation and in the field is given in detailed tabulated form, in which all the species are listed, together with their respective ranges. The floras of the several subdivisions indicated are discussed in some detail. The correlative comparison of the horizons of the southern field with those of the other anthracite fields is of special interest.

A considerable portion of the memoir is devoted to the description of the most characteristic species of plants found in the Pottsville, and to notes on many other species.

One of the most surprising, as well as interesting, facts observed in the study of the Pottsville floras is the large element that is common in the latter and to the flora described by Sir William Dawson from the supposed Middle Devonian beds of St. John, New Brunswick. In fact, taking into view the entire flora of the Pottsville formation in the Appalachian province, the identities in the composition of the floras are so great, with respect to both genera and species, as to leave little room for doubt that we have in the "Fern Ledges" at St. John beds of nearly the same age as the Pottsville formation in Pennsylvania. On the whole, while recognizing in the Pottsville formation a group of terranes equal in rank to the Lower Coal-measures, Alleghany series, etc., I do not favor a classification which relegates the entire formation hard and fast to the Upper Carboniferous, but I even anticipate a possible necessity for its permanent division into two groups, the lower of which may eventually perhaps be referred to the Lower Carboniferous. From a paleobotanic standpoint the Pottsville formation is the beginning of Mesocarboniferous.

Briefly stated, the following are some of the general conclusions reached:

No evidence of a marked or general unconformity between the Pottsville and Mauch Chunk is noticeable in this region, though at various points within several hundred feet of the strata beds of small bowlders or coarse conglomerates are imposed, in knife-edge contact, on the distinctly uneven surfaces of olive-green mud-beds.

The flora in the roof of the Buck Mountain coal, or its supposed equivalents, at the base of the Lower Coal-measures at Pottsville is a typical Coal-measures flora, very distinct from the floras typical of the Pottsville formation.

The fossil plants of the Pottsville formation in the type region exhibit a rapid development and series of changes or modifications, which, if treated with great systematic refinement, are of high stratigraphic value. With the exception of the species from the topmost beds of the formation, the ferns are, in general, readily distinguished specifically from those at the base of the Lower Coal-measures, or Alleghany series, as recognized in the northern United States, while the floras of the lower portions of the section are found, in passing downward, to bear still less resemblance to those of the Lower Coal-measures. Two principal divisions of the formation, to which comparatively few fern species are common, are recognized. These divisions, which coincide with the natural grouping of the Lykens coals, are here termed the Lower Lykens division and the Upper Lykens division. A portion, including about two hundred feet of the type section between these two paleontologic divisions, contains a mixed flora, and has been temporarily designated the Lower Intermediate division.

Further paleontologic study of the Pottsville formation appears to fully confirm the earlier conclusion, based on the examination of the plants, that the thinner sections of the formation along the northern and western borders of the Appalachian trough do not contain beds as old as those in the lower portion of the thick sections along the eastern border, *e. g.*, in the Schuylkill and Great Flat Top regions. The positions of the respective floras in the sections plainly indicate a transgression of the sea toward the north and west during Pottsville time.

Both lithologically and paleontologically the Pottsville formation constitutes a division of the Carboniferous coördinate with the Lower Coal-measures, Alleghany series, etc. As such it forms the lower member of what may in a broad sense, be termed the Mesocarboniferous in the Appalachian province.

The lowest beds in the thickest sections, which appear to be continuous by transition with the deposition of the Maunch Chunk red shales, are perhaps to be regarded as coarse, coast-detrital redepositions, contemporaneous with the uppermost beds of the red shale or marine Lower Carboniferous sediments of other regions.

The flora of the Pottsville formation is so far identical, in both its generic and its specific composition, with that from the supposed Middle Devonian beds at St. John, as to leave no room for a great difference in the age of the latter.

CHARLES R. KEYES.

Iowa Geological Survey; SAMUEL CALVIN, State Geologist; A. G. LEONARD, Assistant State Geologist; Annual Report for 1900 (Vol. XI, 519 pages, 12 plates, 43 figures, 9 maps. Des Moines, 1901).

In scope and style this report follows closely the previous volumes of the series. It includes the usual administrative reports, the statistical reports of the mineral production, and detailed reports on Louisa, Marion, Pottawattamie, Cedar, Page, and Clay and O'Brien counties, the last two being treated together. These reports are written by J. A. Udden, B. L. Miller, J. A. Udden, W. H. Norton, Samuel Calvin, and T. H. Macbride respectively. They contain a careful review in each case of the local geology and serve to put on record facts and observations which may be used in later discussion of the theoretical problems involved. Following the usage of the survey, these discussions are taken up as fast as the development of the general survey allows them to be intelligently discussed. In the case of Louisa county, for example, the problems of the drift of that region have already been discussed in their theoretical phases in Mr. Udden's report on Muscatine county, Mr. Norton's report on Scott county, and Mr. Leverett's well-known monograph.[1] In the Louisa report Mr. Udden gives many interesting and valuable details confirmatory of the general conclusions already reached. In the Cedar county report, on the other hand, Mr. Norton places clearly before the reader the facts as to the structure and situation of the beautiful land forms to which McGee has given the name *paha*, and also states the various hypotheses which have been suggested for their origin. He makes no attempt, however, to balance the probabilities and reach a decision in the matter. The same method is observed in the discussion of the high dips observed in the Gower limestone of the Niagara. This is confessedly a difficult problem, and its solution is wisely left until the whole area shall have been studied.

---

[1] U. S. Geol. Surv., Mon. XXXVIII. The Illinois Glacial Lobe.

In the reports on Page and Pottawattamie counties the survey takes up the southwestern portion of the state. Apparently most interesting results are likely to follow this survey. Mr. Calvin's suggestion that the drift of Page county may be the pre-Kansan instead of the Kansan fits in with many of the known facts of the field in Iowa and neighboring states. It is a far-reaching suggestion, and the development of the hypothesis will be watched with interest. In Pottawattamie county the facts are possibly susceptible of either interpretation. Mr. Udden does not, however, discuss the probabilities. His report is particularly interesting to the general student in the large use which he makes of mechanical analyses in the study of the drift. This is a method which seems likely to become more and more useful in the study of unconsolidated materials. The important results already reached by Whitney in the study of soils seem merely the forerunners of what is possible on a wider application of the method to the study of geological problems in general. Mr. Udden's hypothesis of the origin of the rivers of the county is ingenious, but the argument is not altogether convincing. The suggestion that the surface of a great ice sheet would afford a better opportunity for the development of such a regular system of rivers than the drift surface left by the melting away of the ice seems open to question. The surface of the Kansan drift, it is true, is everywhere notably even. It is impossible, however, to suppose that so thick and widespread a drift sheet as this would be laid down without the development of moraines and other surface irregularities. Yet such irregularities, where they now occur, are very faint, and are apparently the marks of much greater original irregularities. The present plane surface seems likely to be a result of erosion itself. Remembering the long period since these older drifts were deposited and the manifestly great erosion to which they have been subjected, it seems a bit fanciful to believe that the streams now have a general course originally developed on the top of the ice. It is also difficult to imagine how streams, granting that they were developed on the ice in a symmetrical fashion, could be transferred to the drift surface during the melting of the ice without disturbance of their arrangement. If the disappearance be supposed to be accomplished by frontal retreat, the edge of the ice itself will give a sufficiently marked line for the development of the cross streams, and the major streams would in all probability be developed normal to the ice front. This apparently accords with the facts of the field and does not involve the difficulty of accounting for the development of a vigorous surface drainage on the ice and its transfer to the drift surface without notable destruction of its arrangement. The whole problem is an interesting one, and certainly Mr. Udden's hypothesis, if valid, is widely applicable. If we are to be able from the present stream arrangement to infer so much regarding the condition during glacial times a considerable step in advance is made. This fact warrants the closest skepticism in examining the hypothesis.

The volume as a whole is one which geologists will welcome. While the long series of annual reports made up of separate county reports is confusing to one not familiar with the region, the survey is systematically building up a work which will prove valuable not only to students of the local geology but to geologists in general. The work will lend itself to final summary treatment, and in the meantime the county reports not only serve a useful purpose locally, but enable outsiders to keep in touch with the results. The progress map of the drift mapping (plate II) is particularly valuable in this regard.

H. F. B.

Beach Structures in the Medina Sandstone. By H. L. Fairchild. American Geologist, Vol. XXVIII, pp. 9–14, plates 2–6.

In the July number of the *American Geologist* Professor H. L. Fairchild discusses the "Beach Structures in the Medina Sandstone." The features considered are certain troughs and swells of a breadth ranging from thirty to eighty feet. These are assumed to be of the same nature (probably in some cases the same examples) as those which formed the basis of Dr. Gilbert's theory of "giant ripples." Gilbert had concluded (*Bulletin Geol. Soc. Amer.*, March 1899) that with "certain combinations of amplitude and frequency" the largest ocean waves might produce ripples having a length equal to half the height of the wave. The supposed giant ripples observed at Lockport, N. Y., reached a length of thirty feet, implying waves sixty feet high in the Medina sea. Fairchild explains the same features as spits or rather beach ridges, sometimes observed in series of as many as four crests with intervening troughs. Of the fifteen halftones with which the article is illustrated, about one third are clear enough to show without doubt that the features referred to are of the same nature as those discussed and figured in Gilbert's article. Four of the cuts show sand ridges on the present shore of Lake Ontario which are supposed to exemplify the process by which the features in the Medina were made. The remaining cuts and a few expressions in the article leave it in doubt as to whether the features observed were all of the type from which Gilbert's conclusions were drawn. The latter found no intervals of more than thirty feet from crest to crest; the article under discussion refers to similar spacings of eighty feet. Gilbert's discussion of the features as ripples implies a symmetry or at least unity in the trough by which its breadth could be fairly estimated when only a portion could be seen. Fairchild speaks of the trough as only a "negative or passive element" which may have any width varying with the accidents which determine the location of a new beach ridge. The observations of both, and both interpretations, involve abundant cross bedding. It would seem that the two processes hypothesized would produce different dispositions of this crossbedding, as well as differences in the symmetry of the trough. Gilbert shows by diagram the necessary arrangement of the crossbedding under various suppositions as to the shifting of the ripple system during deposition. It is quite improbable that the patterns in vertical cross section thus produced would be duplicated in a series of beach ridges. In the latter case the lamination on the landward side of an outer ridge should be plainly distinguishable from the lamination on the lakeward slope of the next ridge within. The lamination corresponding to this latter slope should disappear only in the most extreme cases of landward migration of the ridge, a condition quite improbable where a series of ridges is produced. Fairchild's objection that ripple marks are not found of intermediate sizes between eight inches and the "giants" is certainly of interest.

N. M. F.

The Beaufort's Dyke, off the Coast of the Mull of Galloway. By H G. KINAHAN. Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1.

In the Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1, Mr. H. G. Kinahan, District Surveyor (Retired), H. M. Geological Survey, describes "The Beaufort's Dyke, off the Coast of the Mull of Galloway." This "dyke" is a deep trough in the bed of the Irish Sea nearer the coast of Scotland. The plate accompanying the article reproduced from the Admiralty charts, shows a long line of soundings of 100 to 148 fathoms, surrounded by a comparatively level bottom 70 or 80 fathoms deep. Attention is just now directed to these depths by the proposition to construct a tunnel from Scotland to Ireland. The geological interest lies in the fact that in this trough "there are sands, gravels and their adjuncts, at depths of from 120 to 144 fathoms that are carried backward and forward similarly to those on an ordinary sea beach." This is much deeper than the waves and currents even on most exposed coasts have been supposed to act. The vigor with which this deep washing occurs may be inferred from figures given in a table, which show that at one point the bottom was cut down by erosion from a depth of 117 fathoms to a depth of 146 fathoms from 1894 to 1897 or nearly 60 feet a year. At other times filling was similarly rapid. The origin of the dyke or trough itself is left in doubt but faulting and glacial action are suggested. The origin of currents capable of acting at that depth is the main subject of interest. It is assumed that while the effect of wind waves and tide waves is reduced to zero at moderate depths there are deep currents induced by these superficial waves, to the depth of whose action no definite limit is assigned. The author contrasts these currents with the ordinary tidal races which may be supposed to erode shallow places more than deep ones. He refers to his former publications for detailed proof that denudation by these currents in question "is in ratio to the depth of the water." The whole article goes to show that when the movements of water are controlled by channels or reflected from irregular shores, the coarseness of the sediments at given depths bears little relation to the mathematically computed power of the water for those depths.

N. M. F.

Recent Publications

—American Institute of Mining Engineers, Transactions of the. Vol. XXX. February, 1900, to September, 1900, inclusive. New York, 1901.

—Baker, Frank Collins. 1. Digitations of the Mantle in Physa. 2. Description of a New Species of Limnæa. Bulletin of the Chicago Aeadmy of Sciences, Vol. II, No. 4. July 1, 1901.

The Molluscan Fauna of the Genesee River. [Reprint from the American Naturalist, Vol. XXXV, No. 416, August, 1901.] Ginn & Co., Boston.

—Bieler, Theodore. Étude Préliminaire sur le Modelé Glaciaire et le Paysage Drumlinique Dans la Plaine Vaudoise. [Bulletin de la Société Vaudoise des Sciences Naturelles. 4^e^ S., Vol. XXXVII, No. 139.] Librairie F. Rouge, Rue Haldimand, Lausanne, Mars, 1901.

—Dean, Bashford. Paleontological Notes. I. On Two New Arthrodires from the Cleveland Shale of Ohio. II. On the Characters of Mylostoma Newberry. III. Further Notes on the Relationships of the Arthrognathi. Plates III–VIII. [New York Academy of Sciences, Memoirs, Vol. II, Part III, 1901.] Published by the Academy, New York, 1901.

—Dewalque, G. Mélanges Géologiques. Hutiéme & Derniére Série. Bruxelles et Liége, 1897–1900.

—Ells, R. W. The Devonian of the Acadian Provinces. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 6, for July, 1901, issued August 10, 1901.]

—Hamberg, Axel. Geologiska och Fysiskt-Geografiska Undersökningar Sarjekfjällen. Tryckt i Central-Tryckeriet, Stockholm, 1901.

—Hollender, Artur. Om Sveriges Nivåförändringar efter Människans Invandring. Akademisk Afhandling som med Tillstånd af vidtberömda filosofiska Fakultetens i Upsala mattatisk-naturvetenskapliga Sektion till offtentlig Granskning framställes. [Å Lärosalen N:r 7 Onsdagen den 29 Maj, 1901, kl. 4 E. M.] P. A. Norstedt & Söner, Stockholm, 1901.

—Holmes, William H. Review of the Evidence Relating to Auriferous Gravel Man in California. [From the Smithsonian Report for 1899, pp. 419–472, with Plates I–XVI.] Washington, 1901.

—Iowa Geological Survey, Vol. XI, Annual Report for 1900. Samuel Calvin, State Geologist; A. G. Leonard, Assistant State Geologist. Des Moines, 1901.

—Iowa, State University of. Bulletin from the Laboratories of Natural History, Vol. 5, No. 2. Iowa City, Iowa, May, 1901.

—JAQUET, J. B. The Iron Ore Deposits of New South Wales; with maps, plates, and sections. [Memoirs of the Geological Survey of New South Wales; Geology, No. 2.] Sydney, 1901.

—JEVONS, H. STANLEY. A Numerical Scale of Texture for Rocks. [Extracted from the Geological Magazine, Decade IV, Vol. V, No. 408, p. 255, June, 1898.]

A Systematic Nomenclature for Igneous Rocks. [Extracted from the Geological Magazine, N. S., Decade IV, Vol. VIII, pp. 304–316, July, 1901.] Dulau & Co., 39 Soho Square, W., London.

—KERFORNE, F. Étude de la Région Silurique Occidentale de la Presqu'ile de Crozon (Finistére). Imprimerie Fr. Simon, Successor de A. Le Roy, 8, Rue des Carmes, Rennes, 1901.

—KLAUTZSCH, A. Bericht über Endmoränen und Tiefbohrungen im Grundmoränengebiete des Blattes Rastenburg (Ostpreussen). [Separatabdruck aus dem Jahrbuch der königl. preuss. geologischen Landesanstalt für 1900.] Berlin, 1901.

—LAY, H. C. Recent Geological Phenomena in the "Telluride Quadrangle" of the U. S. Geological Survey in Colorado. [Transactions of the American Institute of Mining Engineers.]

—LEONARD, ARTHUR GRAY. The Basic Rocks of Northeastern Maryland and their Relation to the Granite. [From the American Goologist, September, 1901.]

—LIVERSIDGE, A. On the Crystalline Structure of some Silver and Copper Nuggets (with Plates VII–IX). On the Crystalline Structure of some Gold Nuggets from Victoria, New Zealand, and Klondyke (with Plates X–XIII). [Reprinted from the Journal and Proceedings of the Royal Society of N. S. Wales, Vol. XXXIV.]

—MOURLON, MICHEL. Sur l'État d'Avancement du Répertoire Universel des Travaux Concernant les Sciences Géologiques (Bibliographia Géologica). [Extrait des Annales (Bulletins des séances) de la Société royale Malacologique de Belgique. Tome XXXVI, 1901, pp. XVI à XX.] P. Weissenbruch, 49 Rue du Poinçoin, Bruxelles, 1901.

—NORTON, WILLIAM HARMON. Geology of Cedar County. [From Iowa Geological Survey, Vol. XI; Annual Report, 1900, pp. 279–396.] Des Moines, 1901.

—**Pearson**, H. W., Duluth, Minn. Oscillations in the Sea-Level. [Extracted from the Geological Magazine, N. S., Decade IV, Vol. VIII, April, May, and June, 1901.] Dulau & Co., 39 Soho Square, W., London.

—**Phillips, William Battle**. Texas Petroleum. [Bulletin of the University of Texas, No. 5. The University of Texas Mineral Survey Bulletin No. 1, July, 1900.]

—**Radde, Gustav**. Museum Caucasicum. III. Tiflis, 1901.

—**Richthofen, Ferdinand von**. Geomorphologische Studien aus Ostasien Sitzung der physikalisch-mathematischen Classe vom 18. Juli. [Zitungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, 1901. XXXVI.]

—**Siebenthal**, C. E. The Silver Creek Hydraulic Limestone of Southeastern Indiana. [From the Twenty-fifth Annual Report of the Department of Geology and Natural Resources of Indiana, 1900.]

—**Smyth**, C. H., **Jr**. Geology of the Adirondack Region. [Reprinted from Appalachia, Vol. IX, No. 1, 1899.]

Report on Crystalline Rocks of the Western Adirondack Regions.

Sketch of the Physiographical Development of the Adirondack League Club Preserve. [Prepared for the Club by permission of the Director of the United States Geological Survey.]

—**Spurr**, J. E. Origin and Structure of the Basin Ranges. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 217–270. Pls. XX–XXV.] Rochester, April, 1901.

—**Stoney**, G. **Johnstone**. Survey of that Part of the Range of Nature's Operations which Man is Competent to Study. [From the Smithsonian Report for 1899, pp. 207–222, with Fig. 1.] Washington, 1901.

—**Udden**, J. A. Geology of Louisa county. [From Iowa Geological Survey, Vol. XI; Annual Report, 1900, pp. 55–126.] Des Moines, 1901.

Geology of Pottawattamie County. [From Iowa Geological Survey, Vol. XI; Annual Report, 1900, pp. 201–277.] Des Moines, 1901.

—**Vaughan**, T. **Wayland**. Some Fossil Corals from the Elevated Reefs of Curaçao, Arube, and Bonaire. [From the "Sammlungen des Geologischen Reichs-Museums in Leiden," Series 3, Bd. II, Heft 1.] E. J. Brill, Leiden, 1901.

—Washington Academy of Sciences, Proceedings of the:

Papers from the Harriman Alaska Expedition, XXII, Entomological Results (14): The Odonata. By Rolla P. Currie. Vol. III, pp. 217–223, July 13, 1901.

Papers from the Harriman Alaska Expedition, XXIII, The Ascidians.

By W. E. Ritter, University of California. Vol. III, pp. 225–266. Pls. XXVII–XXX, July 13, 1901.

A New Species of Olenellus from the Lower Cambrian of York County, Pennsylvania. By Atreus Wanner. Vol. III, pp. 267–272. Pls. XXXI–XXXII, July 13, 1901.

Synopsis of the Rice Rats (Genus Oryzomys) of the United States and Mexico. By G. Hart Merriam. Vol. III, pp. 273–295, July 26, 1901.

Papers from the Harriman Alaska Expedition, XXIV, The Willows of Alaska. By Frederick V. Coville. Vol. III, pp. 297–362. Pls. XXXIII–XLII, August 23, 1901.

Papers from the Hopkins-Stanford Galapagos Expedition, 1898–9: I, Entomological Results (1): Hemiptera. By Otto Heidemann, U. S. Department of Agriculture. Vol. III, pp. 363–370, August 23, 1901.

—WHITFIELD, R. P. Note on a Very Fine Example of Helicoceras Stevensoni Preserving the Outer Chamber. [Author's Edition, extracted from Bulletin of the American Museum of Natural History, Vol. XIV, Article XVI, p. 219. New York, July 29, 1901.]

Notice of a Remarkable Case of Combination between Two Different Genera of Living Corals. [Author's Edition, extracted from Bulletin of the American Museum of Natural History, Vol. XIV, Article XVII, pp. 221, 222. New York, July 29, 1901.]

Some Observations on Corals from the Bahamas, with Description of a New Species. [Author's Edition, extracted from Bulletin of the American Museum of Natural History, Vol. XIV, Article XVIII, pp. 223, 224. New York, July 29, 1901.]

—WINCHELL, N. H. Editorial Comment: The Archean of the Alps. [From the American Geologist, September, 1901.]

THE
JOURNAL OF GEOLOGY

OCTOBER–NOVEMBER, 1901

INDIVIDUALS OF STRATIGRAPHIC CLASSIFICATION.

INDIVIDUALS TO BE DISTINGUISHED.

SHOULD geologists map the record of physical conditions or the record of biological conditions—rocks or fossils? Both, but with distinction.

When the geologist enters the field to do stratigraphic work, one of the first problems to confront him is where he shall divide the series of rocks he is studying; and often, when reading a paper, we are perplexed to know where these lines have been drawn and what the divisions are intended to represent. This discussion is an effort to arrive at a better understanding of what we classify and what may be mapped.

Since the earliest days of geologic work there has been recognition of different kinds of rocks. For many years geologists compared the various rocks they found, and correlated them from continent to continent on the basis of like physical conditions represented in the similar lithologic characters of the rocks, Identity of physical conditions was interpreted as indicating the same date, but we now know that the physical characteristics of rocks are repeated from time to time, and are diverse in different provinces at the same time, and that therefore they do not afford criteria of contemporaneous deposition. Furthermore, conditions of sedimentation are related to currents, shores, and other moving features; the zones of deposition may migrate with these features, and an identical sediment accumulate in the migrating zone successively, not simultaneously, over adjacent areas.

After the days of William Smith a second class of divisions arose—divisions based on the fossils which the rocks contain. Fossils were found to occur in certain associations, which were called faunas, and these became the basis of a classification of rocks. On the hypothesis of special creations and destructions each fauna, wherever occurring, represented a certain date, and thus faunas became the significant figures expressing age. But special creation has given way to evolution, and we recognize migration of faunas as a fact. For instance, Walcott has stated that it took a long time for the Olenellus fauna to move round the globe. A greater or less time interval must elapse between the earliest appearance of a fauna at one place and its earliest appearance at another place remote from the first, hence, a fauna does not indicate a precise date in the narrow sense in which it was once taken. Professor H. S. Williams has pointed out that in a wider sense any fauna endures a length of time, from its initial appearance somewhere to its extinction everywhere; and this interval is an episode of evolution which has a fixed place in geologic history. In that sense faunas have definite time values, but the discovery of that value in any case is dependent on refined and extensive paleontologic research.

Accordingly, when studying a stratigraphic series, a geologist may recognize distinctions of lithologic character, variations of faunal content, and succession of physical or faunal changes. The differences enable him to define lithologic individuals, faunal individuals, and time intervals. Though often intimately related, sediments and faunas are by no means necessarily bounded by the same limits in space or in time; they constitute not identical but unlike things. They may migrate together or independently. Either may cease and the other continue. When each of them has been described and discusssed in its local and general relations, the problem of correlation in terms of earth history may be hopefully attacked; but when strata and faunas are treated under one name, confusion ensues and the conclusion becomes a guess.

It follows that we need to recognize, define, and name three separate things: (1) lithologic individuals; (2) faunal individuals; and (3) time intervals.

LITHOLOGIC INDIVIDUALS.

Definition.—Some twelve years ago there was held a conference of the geologists of the United States Geological Survey, and at that time the basis for the Geologic Atlas of the United States was laid. That foundation was planned upon the simplest lines. It was proposed that the maps should exhibit the distribution of local lithologic individuals.

Referring to the *Tenth Annual Report*, Part I, in the account of that conference we find the following statement (pp. 63–64): "Among the clastic rocks there shall be recognized two classes of divisions, viz., structural divisions and time divisions." Observe that time is set off in contrast to structure, and that structure is not defined by time. Then, defining structural units, the report says (p. 64): "The structural divisions shall be the units of cartography, and shall be designated *formations*. Their discrimination shall be based upon the local sequence of rocks, lines of separation being drawn at points in the stratigraphic column where lithologic characters change." Proceeding to emphasize that, the report further says (p. 64): "Each formation shall contain between its upper and lower limits either rock of uniform character or rock uniformly varied in character." By the latter phrase it was recognized that there might be groups of lithologic individuals which singly could not be mapped because too small—a difficulty which had to be met from the practical side. Furthermore, the report says: "As each lithologic unit is the result of conditions of deposition that were local as well as temporary, it is to be assumed that each formation is limited in horizontal extent; the formation should be recognized and should be called by the same name as far as it can be traced and identified by means of its lithologic characters, *aided by its* "certain combinations of amplitude and frequency" the largest ocean waves might produce ripples having a length equal to half the height of the wave. The supposed giant ripples observed at Lockport, N. Y., reached a length of thirty feet, implying waves sixty feet high in the Medina sea. Fairchild explains the same features as spits or rather beach ridges, sometimes observed in series of as many as four crests with intervening troughs. Of the fifteen halftones with which the article is illustrated, about one third are clear enough to show without doubt that the features referred to are of the same nature as those discussed and figured in Gilbert's article. Four of the cuts show sand ridges on the present shore of Lake Ontario which are supposed to exemplify the process by which the features in the Medina were made. The remaining cuts and a few expressions in the article leave it in doubt as to whether the features observed were all of the type from which Gilbert's conclusions were drawn. The latter found no intervals of more than thirty feet from crest to crest; the article under discussion refers to similar spacings of eighty feet. Gilbert's discussion of the features as ripples implies a symmetry or at least unity in the trough by which its breadth could be fairly estimated when only a portion could be seen. Fairchild speaks of the trough as only a "negative or passive element" which may have any width varying with the accidents which determine the location of a new beach ridge. The observations of both, and both interpretations, involve abundant cross bedding. It would seem that the two processes hypothesized would produce different dispositions of this crossbedding, as well as differences in the symmetry of the trough. Gilbert shows by diagram the necessary arrangement of the crossbedding under various suppositions as to the shifting of the ripple system during deposition. It is quite improbable that the patterns in vertical cross section thus produced would be duplicated in a series of beach ridges. In the latter case the lamination on the landward side of an outer ridge should be plainly distinguishable from the lamination on the lakeward slope of the next ridge within. The lamination corresponding to this latter slope should disappear only in the most extreme cases of landward migration of the ridge, a condition quite improbable where a series of ridges is produced. Fairchild's objection that ripple marks are not found of intermediate sizes between eight inches and the "giants" is certainly of interest.

N. M. F.

The Beaufort's Dyke, off the Coast of the Mull of Galloway. By H G. KINAHAN. Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1.

In the Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1, Mr. H. G. Kinahan, District Surveyor (Retired), H. M. Geological Survey, describes "The Beaufort's Dyke, off the Coast of the Mull of Galloway." This "dyke" is a deep trough in the bed of the Irish Sea nearer the coast of Scotland. The plate accompanying the article reproduced from the Admiralty charts, shows a long line of soundings of 100 to 148 fathoms, surrounded by a comparatively level bottom 70 or 80 fathoms deep. Attention is just now directed to these depths by the proposition to construct a tunnel from Scotland to Ireland. The geological interest lies in the fact that in this trough "there are sands, gravels and their adjuncts, at depths of from 120 to 144 fathoms that are carried backward and forward similarly to those on an ordinary sea beach." This is much deeper than the waves and currents even on most exposed coasts have been supposed to act. The vigor with which this deep washing occurs may be inferred from figures given in a table, which show that at one point the bottom was cut down by erosion from a depth of 117 fathoms to a depth of 146 fathoms from 1894 to 1897 or nearly 60 feet a year. At other times filling was similarly rapid. The origin of the dyke or trough itself is left in doubt but faulting and glacial action are suggested. The origin of currents capable of acting at that depth is the main subject of interest. It is assumed that while the effect of wind waves and tide waves is reduced to zero at moderate depths there are deep currents induced by these superficial waves, to the depth of whose action no definite limit is assigned. The author contrasts these currents with the ordinary tidal races which may be supposed to erode shallow places more than deep ones. He refers to his former publications for detailed proof that denudation by these currents in question "is in ratio to the depth of the water." The whole article goes to show that when the movements of water are controlled by channels or reflected from irregular shores, the coarseness of the sediments at given depths bears little relation to the mathematically computed power of the water for those depths.

N. M. F.

Permo-Carboniferous fauna. This alternation of strata of different lithologic character can be subdivided in great detail when the exigencies of mapping require it. *The important lines limiting the Rico formation above and below cannot be drawn upon lithologic grounds.* If lithologic character alone is relied upon for the subdivision of this great complex, embracing strata belonging partly to the Paleozoic and partly to the Mesozoic, the formation units would be of relatively minor importance, and the great historical subdivisions would not be expressed. The criterion of color applied to this complex groups the Permo-Carboniferous with the Trias. This has been done in previous general discussions of this complex in this region. In fact, the Permo-Carboniferous beds should be grouped with the Carboniferous if the larger elements of time division are to receive recognition upon the geologic map of the Rico quadrangle. (Italics the present writer's.)

There are two questions involved: First, what Mr. Cross's map expresses; second, what it should express. The Hermosa, Rico, and Dolores are clearly not formations in the sense defined in the *Tenth Annual Report*, for lithologic continuity is divided at the top and bottom of the Rico on the basis of contained fossils. They are intended to be faunal divisions, but their limits are very ill defined, since fossils are commonly so few in the Red Beds that the finding of them higher or lower in the series is a matter of accidental discovery rather than of occurrence. The map appears, then, to express indefinitely the arbitrary application of a time scale (Paleozoic, Mesozoic or Carboniferous, Permo-Carboniferous, Triassic) to a series which is capable of division into lithologic individuals. Were it so divided it would yield a record of physical conditions, a record which is now obscured by this classification.

It is an important fact that conditions of erosion and deposition were continuously favorable to the accumulation of red sediments while biologic migration or evolution modified the organisms present from Paleozoic to Mesozoic types. But in discussing the formations their continuity is the essential, just as in describing the faunas their discontinuity would be. To impose the division of the latter upon the lithologic individual is misleading, and to call the faunal units "formations" in a publication for which that term has been accurately defined is a misuse of the word.

A very similar case is that of the Shenandoah limestone, which carries Cambrian fossils in its lower portion and Calciferous fossils near the top. But, though it thus corresponds to parts of two great periods, as we usually classify geologic time, it is mapped as one formation because it is a lithologic unit.

Formation names. — "The formation should be recognized and should be called by the same name as far as it can be traced and identified by means of its lithologic characters, aided by its stratigraphic association and contained fossils." Following this rule (*Tenth Annual Report*, Part I, p. 64), various cases may arise, some of which are illustrated in the accompanying diagrams.

Figure 1 shows the *m* shale passing into a limestone which retains identical stratigraphic associations. Being exactly continuous stratigraphic units, they should retain the same geographic name on grounds of convenience and simplicity.

Figure 2 shows the *m* shale grading into a limestone with prolonged overlap, so that the two rocks must be discriminated in one area. Not only are they lithologically different but they have different stratigraphic associations, and they should receive distinct geographic names: *m* shale and *n* limestone.

Figure 3 shows the *m* shale continuing as an individual with reduced thickness into new stratigraphic associations. Individuality is not dependent on thickness nor on stratigraphic association only; it is determined by continuity, and the formation may retain its name, *m* shale. But the group *pms* cannot then be called the *m* group, because *m* would have two meanings, one for a simple part, and one for a complex whole.

Figure 4 shows the *m* shale replaced by five formations, two of which, *B* and *D*, are shales like it. Individuality is here lost in multiplicity. Neither *B* nor *D* can be distinguished as representing *m*, which must, accordinly, give way where they divide into two. The complex *ABCDE* may be called the *m* group, since it has equivalent stratigraphic associations with *m*.

Figures 5 and 6 illustrate the occurrence and naming of local lenses in a formation where such divisions are not of sufficient extent to justify a distinct series of names for the lens and the parts of the formation above and below it. One lens may receive the formation name, but two or more must be named distinctly.

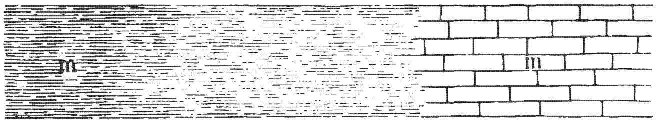
Figure 7 presents the case of a formation which is a least practicable lithologic individual for mapping, but which includes fractional parts that are important in discussion. The fractional character of the parts may be indicated by calling them members, each member being given a distinctive geographic name.

Lithologic individual and thickness.—Thickness is not an essential character of a lithologic individual. Layers, strata, beds, and their complexes vary so generally in this respect that individuality based upon constancy thereof must be lost in a short distance. And if thickness be not constant for any one individual, still less can volume be considered an element of the definition of formations in general. Lithologic individuality knows no such limits. Continuity of rock character is the essential core of the definition, and this may extend through a hundred or a thousand feet or more or less.

The writer has avoided the use of the phrase "lithologic unit," because discussion developed the fact that, in the minds of some, unit means a definite quantity, and these persons think that a thick formation should be a group or series, because of its magnitude. Not volume, but uniformity of constitution, defines a lithologic individual or "formation."

Lithologic individual and time.—Thickness of strata, at right angles to bedding, is considered a measure of the epoch of deposition, due account being taken of the estimated rate. Thus for that particular place the lithologic unit is significant of definite lapse of time. It bears, however, no mark of date. If we trace the formation a hundred or a thousand miles, and again measure its thickness, another determination of an epoch is obtained, again without date. Are the epochs identical? The common assumption is that they are, and one reads of the epoch of the Dakota formation without reference to locality. Thus used, the phrase should mean all the time during which the Dakota sandstone was spread from its eastern to its western

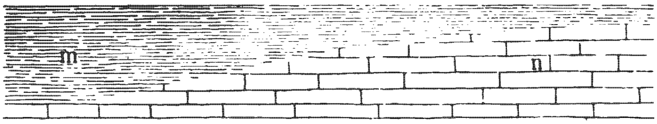
I



m *shale or formation*

m *limestone or formation*

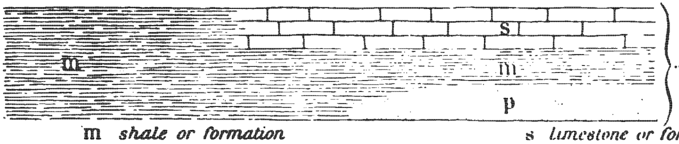
II



m *shale or formation*

n *limestone or formation.*

III

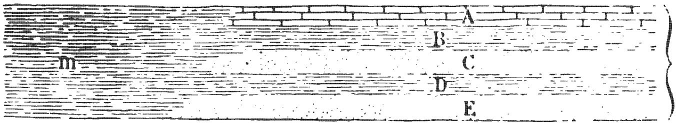


m *shale or formation*

x group

s *limestone or formation*
m *shale or formation*
p *sandstone or formation*

IV

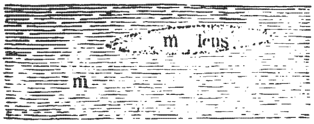


m *shale or formation*

m *group*

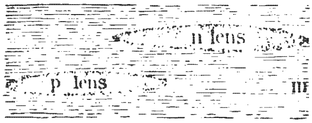
A *limestone or formation*
B *shale or formation*
C *sandstone or formation*
D *shale or formation*
E *sandstone or formation*

V



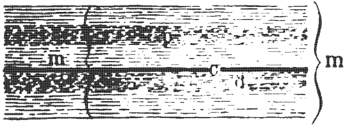
m *shale or formation*
and m *lense*

VI



m *shale with* n *and* p
sandstone lenses

VII



m *shale or formation including* p *fire clay member,* c *coal member, and* d *fire clay member* limit. Since that transgression took a long time, the eastern Dakota sandstone is older than the western; and as the advancing zone of sand accumulation, following the shore, was in turn followed by a zone of shale deposit, the eastern sands were being buried under Benton shale while the western sands gathered. When the transgression ceased and Niobrara chalk was laid down, the conditions were more nearly uniform throughout the sea. Niobrara then probably marks approximately one and the same epoch throughout its extent. Benton may do so in less exact degree; and Dakota corresponds at an eastern point to the beginning, at a western to the closing, of the cycle of deposits.

It is convenient to conceive the time scale as marked by horizontal lines. On such a scale the Dakota formation would be represented by a diagonal line, and the Niobrara by a nearly horizontal line.

The writer does not put these ideas forward as new; but in defining a formation it is important to clear away certain misleading conceptions that appear in the literature and in discussion of the points at issue. Only at a particular place does a formation belong to a definite age: when traced to another locality it may be older or younger.

FAUNAL UNITS.

Classification by faunas.— The term faunal unit or individual is here used as a parallel to lithologic individual, to designate a set of strata characterized by a common fauna. The writer does not undertake to say whether a fauna should be defined by varieties, species, or genera; by recognition of one or many associated organisms. It may be granted that a fauna is something which each working paleontologist will define for himself within certain broad limits, just as lithologic character is something which each stratigrapher defines for himself within certain limits. But classification of strata by faunas is a different thing from classification by formations.

Professor Williams, in 1897, published a paper on dual nomenclature, in which he clearly stated the distinction which the present writer would now emphasize between a lithologic individual and a faunal unit.

Following the language in which a formation is defined in the *Tenth Annual Report*, a faunal unit may be defined as follows:

LITHOLOGIC INDIVIDUAL.	FAUNAL UNIT.
"The structural divisions shall be units of cartography, and shall be designated *formations*. Their discrimination shall be based upon the local sequence of rocks, lines of separation being drawn at those points in the stratigraphic column where lithologic characters change."	The faunal units shall be units of correlation, and shall be designated stages.[1] Their discrimination shall be based upon their fossil content, lines of separation being determined at those points in the stratigraphic column where faunas change.

Pursuing the description of a faunal unit, or stage, we may say further: As a faunal unit is characterized by the life which it contains, and as organisms are migratory, it is not to be assumed that a stage is limited horizontally. It may be recognized in diverse provinces or continents, and therefore the name which a faunal unit receives should not be a local name, but should be applied wherever that unit is recognized.

Distinctions between formation and stage.— A formation is a set of strata characterized by and limited to uniform constitution. A stage is a set of strata containing and limited to a certain fauna.

Lithologic constitution results from conditions which are local and temporary, and which, though migratory, are rarely more than provincial in extent. A fauna, though evolved in adaptation to local conditions, may be capable of world-wide migration. A formation, therefore, is geographically limited; a fauna is not, necessarily.

Physical conditions which determine rock constitution are recurrent and repeat the deposition of similar sediments. But organisms, once extinct, do not reappear. Accordingly, a formation may belong to any geologic age; a fauna belongs only to that age in which it was evolved and died out.

---

[1] The term *stage* is here used provisionally, to afford a word for the purposes of this discussion only.

A principal object in studying formations is to read the physical history of the earth, but the principal object of investigating fossils is to get at the life history. Each is an essential aid to the other, and the time relations of fossils are fundamental. But the two lines of inquiry should not be confused. They are confused when we call a stage a formation, or *vice versa*, or place the limitations of the one upon the other.

STEPS IN GEOLOGIC SCIENCE.

The question with which this article opens may now be given a fuller answer. The first step in the geologic study of any locality is to ascertain the relations of the rock masses, and those relations are most happily expressed in a map which exhibits the distribution of formations. This map illustrates local facts. It can be complete in itself, even though no connection is established between the facts of that particular district and those of the world at large, but if it be a correct map it will fit into the general record when the connections are traced.

The second step in geologic investigation is the detailed study of faunas and their distribution in stages. To this second step the first is an essential, as a good topographic map is to both. Through close analysis of the faunas and comparative study of their distribution, the data may be gathered for a map of the stages represented in the district. This map of stages may in some cases resemble closely that of the formations, but in others there will be marked differences.

With the development of maps showing the distribution of stages we may arrive at correlation of events, and thus be able to compare physical conditions the world over, fitting into its place with some degree of exactness the record of the formations for any locality. Thus correlation is the third step, a step which may be facilitated through other lines of research, but which is fundamental in broad studies of the earth's history.

With a better knowledge of the physical geography of the globe at successive epochs we may more hopefully attack the great problems of mountain growth, continental development, and earth dynamics. But our first work is to map the lithologic individuals, while our associates, the paleontologists, distinguish the faunal units of stratigraphy.

BAILEY WILLIS.

THE DISCRIMINATION OF TIME-VALUES IN GEOLOGY.

THE imperfection of the present systems of classification and correlation of sedimentary rocks concerns more directly the interpretation of the facts than the facts themselves.

The work of the geologists of the United States in mapping and recording the stratigraphic sequence of formations was never more exact and comprehensive. The paleontologist was never more particular in his records of the faunal contents of each formation and fossiliferous zone, and his comparisons were never more full and precise. But the extension of knowledge over vast territory has brought to light hundreds and thousands of outcrops of the same formations, showing a diversity of faunal composition which cannot be translated entirely into difference in geologic age.

So long as surveys were confined to local areas separated by spaces across which the continuity of formations could not be traced, it was practicable to use a system of nomenclature and classification in which lithologic formations and their stratigraphic succession were chiefly considered. When, however, the intervals between local areas were filled up and it was necessary to correlate geological sections in which the formational divisions are in part or wholly dissimilar, the duality of the lithologic and biologic facts become apparent. These two sets of facts are entirely different in nature and in origin, and for their scientific discrimination duality of nomenclature is essential.

The confusion of these two kinds of evidence was natural, and has been perpetuated by the common practice of adopting the lithologic formation as the unit of classification, making the time divisions to apply strictly to the formations instead of to the faunas and floras, by which alone the chronologic epochs in which they were formed can be discriminated. This confusion it seen in the discussion of classification and nomenclature in the *Tenth Annual Report* of the United States Geological Survey, and in the legends of the folio maps. For instance, take the Sewanee Folio, Tennessee: The legend is as follows, viz.:

Walden sandstone	Carboniferous.
Lookout sandstone	
Bangor limestone	
Fort Payne chert	
Chattanooga black shale	Devonian.
Rockwood formation	Silurian.
Chickamauga limestone	
Knox dolomite	

According to the rules in the *Tenth Annual Report*, the first series of names are "*structural divisions* . . . . units of cartography, and shall be designated *formations*" (p. 64).

The second series of names are "*time divisions* . . . . defined primarily by paleontology and secondarily by structure, and they shall be called *periods*" (p. 65).

Although everybody understands what is meant by the classification in the legend, the principle described in the rules is wrong in that the legend on the map refers to a classification of rocks: and the real fact in the case is that in the Sewanee quadrangle the Walden, Lookout, Bangor and Fort Payne formations together constitute the Carboniferous *system*, and the map makes no record of periods of time but only of formations of rocks. The Devonian system of that quadrangle consists of the one Chattanooga formation; and the Rockwood, Chickamauga, and Knox formations are the only representatives of the Silurian system recognized on the sheet.

The European nomenclature avoids this confusion by recognizing a set of stratigraphic names and their categories; with a corresponding set of categories for the chronologic classification—the names of the divisions being the same in both the stratigraphic and chronologic scales. Instead of referring all stratigraphic divisions to one category (the formation), different categories are used for formations of different relative size; making the list of names to be group, system, series, stage, as adopted by the international Congress. Each of these stratigraphic divisions has its corresponding chronologic category, viz., era, period, epoch, age. The European has no difficulty in expressing on the map, or in discussing, either the time or the structural relations of the formation. On the map, the Walden, Lookout, Bangor, and Fort Payne would be to him four series, together constituting the Carboniferous system. By placing the Chattanooga in the category of series he at once would indicate that he does not regard the formation as necessarily representing the whole Devonian system. On the other hand, when he speaks of the Carboniferous period he is not discussing any local set of formations but the total period of time in which lived a definite set of plants and animals, only a few of which are discovered in any one local formation. There can be no question that the systems of the European geology can be recognized in this country *only* by the fossils—but that does not change them from formational aggregates into time divisions.

The implication in the *Tenth Annual Report* that the divisions which are discriminated by fossils must be chronologic, and not structural, suggests the way in which our usage may be improved; but the fallacy of the principle is seen by noticing that the smaller formations (the series and ètages of the international nomenclature), are to be discriminated by their fossil contents as well as the larger ones (the systems). If discrimination "primarily by fossils" were to be the test as to whether the division were structural or chronologic then formations would become chronologic divisions in every newly surveyed area in which actual lithologic continuity could not be traced to some standard outcrop.

These two sets of facts (structural and paleontological) both have to do with the classification of formations on a time basis; and those who are accustomed to frame their conceptions of geological time on the basis of one set of facts, find difficulty in even conceiving that there is any other basis.

TIME VALUES OF FORMATIONS.

The regular sequence of stratified sediments forms a natural geological column, which, in any particular section of the earth's crust, is so conspicuously subdivided by lithologic differences in kind of sediments that the divisions form the most satisfactory kind of natural time division for geological classification.

These natural, lithologic divisions of the crust of the earth are technically called formations in the nomenclature of the United States Geological Survey. And in any standard section, such as that of New York state, the order, composition and thickness of the several formations is exactly known; and for that section, too, the fossils of each separate formation are known accurately and in large numbers. Geologists have been accustomed to use such a local column of known geological formations as a *standard time scale;* and as examination has extended to sections of the crust in other parts of the continent, the classification and correlation of the other columns have been made to correspond, by correlation, with such a standard column of formations. Two methods have been used in establishing the correlation: (1) by tracing continuity in the lithologic formation; and (2) by recognition of identity of the fossil species contained in the formations. Both of these methods have rested on an assumed interpretation of the facts, the correctness of which may be questioned quite independently of the established fact of continuity or of identity.

The assumptions on which these interpretations rest are that correlations of time relations can be established in the first case by *continuity of lithologic formation*, and in the second case by *identity of fossils.* In regard to the first case, it would be incorrect to say that the assumption is entirely false, for in some cases, and to a limited extent, lithologic continuity of a formation is undoubtedly synonymous with sameness of the period of the sedimentation represented by the formation. But the facts are abundant, and well known to all field geologists, to prove that formational continuity is not co-ordinate with lithologic uniformity; and since our standard definition of a formation

(*Tenth Annual Report*, United States Geological Survey) is based upon its lithologic uniformity, it is certain that in all cases in which the lithologic changes affect the upper or lower limits of a formation (which is expressed by thinning or thickening of the formation) there must be discordance between the formational continuity and the time represented by it. It requires but a moment's reflection, further, to show that two sections in different regions may, on other evidence, be known to represent the same interval of time but present no similarity lithologically; this can receive only the one interpretation that formational discontinuity does represent time uniformity, which is the converse of the original assumption.

In other words, while it is practicable in some cases to assume that formations which are clearly continuous may be deposited during the same period of time, it is clear that lithologic uniformity (by which the continuity of the formation is recognized) is not a safe guide in making chronologic correlations, however much value may be placed upon the lithologic divisions of a standard geologic section, as natural divisions of a geologic column made on a time basis. The tracing of time equivalences by formational continuity is unsatisfactory, not because of any failure on the part of a formation, as a lithologic unit, to represent a definite period of geologic time, but because the time relations of the formation are not expressed by any of the lithologic characters by which one formation is distinguished from another. The confusion the geologist is apt to fall into in discussing this point may be illustrated by the measurement of the altitude of a rock outcropping on a mountain side. The base of the Olean conglomerate, for instance, as it appears at Olean Rock City may represent exactly the altitude of 2,340 feet above the level of the sea (*McKean County Report, Second Pennsylvania Geological Survey*, R. 59), but its altitude above the sea has no relationship whatever to any of its lithological peculiarities. In forming an altitude scale, it is in the region a conspicuous mark for the altitude at which it lies, and if its dip be considered, the continuity of the conglomerate may be relied upon for estimates of approximate altitude. Nevertheless, in itself the formation possesses no altitude value, it is only a conspicuous stratum in the region where it appears, that now lies at a definite elevation above the sea—the amount of the elevation must be determined by other means. It may indicate an altitude already determined, but it has no intrinsic altitude value, and is not a measure of altitude.

In similar manner we may say that the geologic formation, as a lithologic unit, was formed at some definite epoch of geologic time which may be approximately measured by other means; but the amount of time from any datum point to the time when it was formed is not in any degree indicated by the lithologic or structural characters of the formations; and in this sense a formation may be strictly said to possess no intrinsic time value, but to require the "paleontologic evidence" to prove to what "period" of time it belongs. This conclusion might almost be drawn from the statements regarding periods in the *Tenth Annual Report* (p. 65).

It is, however, not necessary to remind geologists that fossils possess a value as means of determining the time relations of formations. But this time value of fossils will be better appreciated if attention be given to the nature of the evidence furnished by fossils regarding the period of time in which they lived.

TIME VALUE OF FOSSILS.

Fossils derive their time-value from the fact that the morphologic characters presented by them are temporary in nature. The form of a trilobite, expressed in its various morphologic characters, was constructed by organisms at a definite period of time in the history of the earth; so that the presence of a fossil trilobite imbedded in a rock formation is direct evidence of the geologic age in which alone the trilobite lived. Hence it is that for the whole surface of the earth fossils become marks of the time divisions and the means of correlating formations on a time-basis; this is the second method of correlation referred to above. Identity of fossils is direct evidence of sameness of time. But extent to justify a distinct series of names for the lens and the parts of the formation above and below it. One lens may receive the formation name, but two or more must be named distinctly.

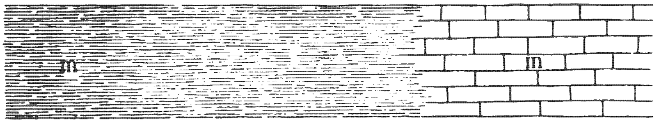
Figure 7 presents the case of a formation which is a least practicable lithologic individual for mapping, but which includes fractional parts that are important in discussion. The fractional character of the parts may be indicated by calling them members, each member being given a distinctive geographic name.

Lithologic individual and thickness.—Thickness is not an essential character of a lithologic individual. Layers, strata, beds, and their complexes vary so generally in this respect that individuality based upon constancy thereof must be lost in a short distance. And if thickness be not constant for any one individual, still less can volume be considered an element of the definition of formations in general. Lithologic individuality knows no such limits. Continuity of rock character is the essential core of the definition, and this may extend through a hundred or a thousand feet or more or less.

The writer has avoided the use of the phrase "lithologic unit," because discussion developed the fact that, in the minds of some, unit means a definite quantity, and these persons think that a thick formation should be a group or series, because of its magnitude. Not volume, but uniformity of constitution, defines a lithologic individual or " formation."

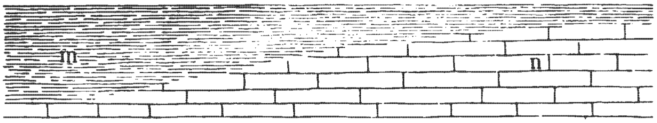
Lithologic individual and time.—Thickness of strata, at right angles to bedding, is considered a measure of the epoch of deposition, due account being taken of the estimated rate. Thus for that particular place the lithologic unit is significant of definite lapse of time. It bears, however, no mark of date. If we trace the formation a hundred or a thousand miles, and again measure its thickness, another determination of an epoch is obtained, again without date. Are the epochs identical ? The common assumption is that they are, and one reads of the epoch of the Dakota formation without reference to locality. Thus used, the phrase should mean all the time during which the Dakota sandstone was spread from its eastern to its western

I



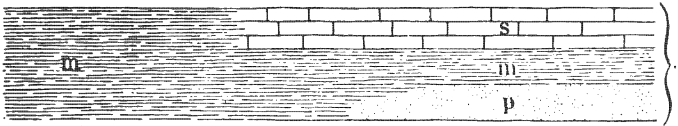
m *shale or formation* m *limestone or formation*

II



m *shale or formation* n *limestone or formation.*

III

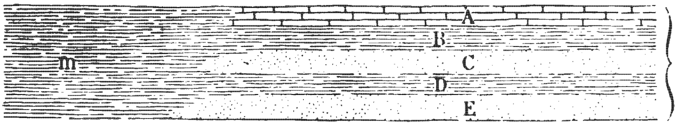


x group

m *shale or formation*

s *limestone or formation*
m *shale or formation*
p *sandstone or formation*

IV

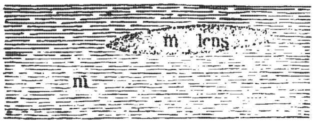


m *group*

m *shale or formation*

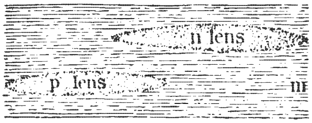
A *limestone or formation*
B *shale or formation*
C *sandstone or formation*
D *shale or formation*
E *sandstone or formation*

V



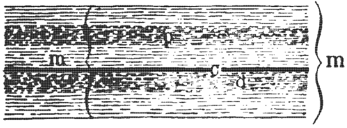
m *shale or formation*
and m *lense*

VI



m *shale with* n *and* p
sandstone lenses

VII



m *shale or formation including* p *fire clay member,* c *coal member, and* d *fire clay member* limit. Since that transgression took a long time, the eastern Dakota sandstone is older than the western; and as the advancing zone of sand accumulation, following the shore, was in turn followed by a zone of shale deposit, the eastern sands were being buried under Benton shale while the western sands gathered. When the transgression ceased and Niobrara chalk was laid down, the conditions were more nearly uniform throughout the sea. Niobrara then probably marks approximately one and the same epoch throughout its extent. Benton may do so in less exact degree; and Dakota corresponds at an eastern point to the beginning, at a western to the closing, of the cycle of deposits.

It is convenient to conceive the time scale as marked by horizontal lines. On such a scale the Dakota formation would be represented by a diagonal line, and the Niobrara by a nearly horizontal line.

The writer does not put these ideas forward as new; but in defining a formation it is important to clear away certain misleading conceptions that appear in the literature and in discussion of the points at issue. Only at a particular place does a formation belong to a definite age: when traced to another locality it may be older or younger.

FAUNAL UNITS.

Classification by faunas.— The term faunal unit or individual is here used as a parallel to lithologic individual, to designate a set of strata characterized by a common fauna. The writer does not undertake to say whether a fauna should be defined by varieties, species, or genera; by recognition of one or many associated organisms. It may be granted that a fauna is something which each working paleontologist will define for himself within certain broad limits, just as lithologic character is something which each stratigrapher defines for himself within certain limits. But classification of strata by faunas is a different thing from classification by formations.

Professor Williams, in 1897, published a paper on dual nomenclature, in which he clearly stated the distinction which the present writer would now emphasize between a lithologic individual and a faunal unit.

Following the language in which a formation is defined in the *Tenth Annual Report*, a faunal unit may be defined as follows:

LITHOLOGIC INDIVIDUAL.	FAUNAL UNIT.
"The structural divisions shall be units of cartography, and shall be designated *formations*. Their discrimination shall be based upon the local sequence of rocks, lines of separation being drawn at those points in the stratigraphic column where lithologic characters change."	The faunal units shall be units of correlation, and shall be designated stages.[1] Their discrimination shall be based upon their fossil content, lines of separation being determined at those points in the stratigraphic column where faunas change.

Pursuing the description of a faunal unit, or stage, we may say further: As a faunal unit is characterized by the life which it contains, and as organisms are migratory, it is not to be assumed that a stage is limited horizontally. It may be recognized in diverse provinces or continents, and therefore the name which a faunal unit receives should not be a local name, but should be applied wherever that unit is recognized.

Distinctions between formation and stage.— A formation is a set of strata characterized by and limited to uniform constitution. A stage is a set of strata containing and limited to a certain fauna.

Lithologic constitution results from conditions which are local and temporary, and which, though migratory, are rarely more than provincial in extent. A fauna, though evolved in adaptation to local conditions, may be capable of world-wide migration. A formation, therefore, is geographically limited; a fauna is not, necessarily.

Physical conditions which determine rock constitution are recurrent and repeat the deposition of similar sediments. But organisms, once extinct, do not reappear. Accordingly, a formation may belong to any geologic age; a fauna belongs only to that age in which it was evolved and died out.

---

[1] The term *stage* is here used provisionally, to afford a word for the purposes of this discussion only.

A principal object in studying formations is to read the physical history of the earth, but the principal object of investigating fossils is to get at the life history. Each is an essential aid to the other, and the time relations of fossils are fundamental. But the two lines of inquiry should not be confused. They are confused when we call a stage a formation, or *vice versa*, or place the limitations of the one upon the other.

STEPS IN GEOLOGIC SCIENCE.

The question with which this article opens may now be given a fuller answer. The first step in the geologic study of any locality is to ascertain the relations of the rock masses, and those relations are most happily expressed in a map which exhibits the distribution of formations. This map illustrates local facts. It can be complete in itself, even though no connection is established between the facts of that particular district and those of the world at large, but if it be a correct map it will fit into the general record when the connections are traced.

The second step in geologic investigation is the detailed study of faunas and their distribution in stages. To this second step the first is an essential, as a good topographic map is to both. Through close analysis of the faunas and comparative study of their distribution, the data may be gathered for a map of the stages represented in the district. This map of stages may in some cases resemble closely that of the formations, but in others there will be marked differences.

With the development of maps showing the distribution of stages we may arrive at correlation of events, and thus be able to compare physical conditions the world over, fitting into its place with some degree of exactness the record of the formations for any locality. Thus correlation is the third step, a step which may be facilitated through other lines of research, but which is fundamental in broad studies of the earth's history.

With a better knowledge of the physical geography of the globe at successive epochs we may more hopefully attack the great problems of mountain growth, continental development, and earth dynamics. But our first work is to map the lithologic individuals, while our associates, the paleontologists, distinguish the faunal units of stratigraphy.

BAILEY WILLIS.

New York was in large measure synchronous with the sedimentation of gray rocks with abundant marine fossils, including *Spirifer disjunctus*, in western New York and Pennsylvania.

If the endurance of the *Spirifer disjunctus* fauna be made the mark of the *Spirifer disjunctus* biochron, it becomes quite possible to state and discuss the facts as they are, and to understand the natural explanation of the facts as a gradual transgression of the shore from which the red sediments were deposited westward with the progress of time. The geochron of red beds began earlier in the scale of biochrons, and as we expand the idea we will discover that it is also earlier in actual geological time, and that the biochron is the measure upon which we must depend in constructing the standard geological time-scale.

THE CONSTRUCTION OF A BIONIC TIME SCALE.

The next question arises, how shall this time-scale be constructed? First, it must be constructed, primarily, on the basis of the bionic values of the fossils. Secondly, the names of the time divisions must be distinct from those used in designating the formational divisions of the rocks. Thirdly, biological names should be chosen for the divisions, and so far as practicable, some abundant or characteristic fossil should furnish the name; as in naming formations the locality in which the formation appears in full force and with full characteristics is used. Fourthly, it cannot be expected that the divisions of an accurate time-scale, based upon many different sources of measurement of the time intervals, will present a continuous series without breaks and without overlapping of the divisions. If a single means of measuring the lapse of time were used, such breaks and lapping might be avoided; only in case the beginning of one species or fauna was everywhere dependent upon the cessation of the preceding one, could the scale be made without liability of failure to meet at the limits of the time intervals indicated. Fifthly, the classification and definition of geological formations should be made, so far as practicable, independent of the fossils or the time relations indicated by them; and the fossils should be used (as now their use is scientifically most valuable) in establishing correlations, not in furnishing definitions. Sixthly, the selection of the grander time divisions should be made to conform, so far as found practicable, with the standard divisions of the formation scale; but their discrimination should be based strictly upon fossil evidence and not upon the lithologic or stratigraphic characters of formations. Seventhly, in forming the time-scale the continuance of the fauna in its integrity, as marked by the dominance of its characteristic species, will constitute a more satisfactory basis of discrimination than the species alone. Slight differences in the aggregate of species found in the successive strata of rocks is quite consistent with the continuance of the fauna in its integrity, and to distinguish the *fauna* as a whole from its local and temporary expression the latter may appropriately be called a *faunule*.

In constructing a time-scale on the basis of the bionic values of fossils, it is practicable to give to the categories now in use greater precision and scientific definition. If geologists chose to adopt the following terms in the restricted sense designated, such a set of terms would prove of great value.

TERMS OF THE BIONIC TIME SCALE.

Chron.—An indefinite division of geological time.

Geochron.—The time equivalent of a formation.

Biochron.—The time equivalent of a fauna or flora.

Hemera.—The technical name for a monobiochron, indicated by the preservation of the individual characteristics of all the species of a local faunule, as shown by the association in the rocks of the same species, in the same relative abundance, size, and vigor. An example is the hemera of *Rhynchonella* (*Hypothyris*) *cuboides*.

Epoch.—The name of a dibiochron, indicating the time equivalent of the endurance of a particular species and of the integrity of the fauna of which it is the dominant characteristic. An example is the *Tropidoleptus carinatus* epoch, which corresponds closely to the limits of the Hamilton formation of eastern New York.

Period.— May be defined as a tribiochron. This is the time equivalent of the continuance of a *genus*. An example is the *Paradoxides period*, which corresponds to the Acadian formation of the Cambrian system.

Era.— May be used to indicate a tetrabiochron; and *Olenide era* would indicate the life range of the family *Olenidae*, corresponding in length, approximately, to the geochron of the Cambrian system, though not strictly so.

Eon.— May stand as the name for a pentabiochron; an example of which is the *Trilobite eon*, the time equivalent of the continuance of the order, or sub-class, *Trilobita*, which closely approximates the length of the Paleozoic geochron.

CLASSIFICATION AND NOMENCLATURE OF THE TRILOBITE EON (PALEOZOIC) CONSTRUCTED ON THE BASIS OF THE BIONIC VALUES OF FOSSILS.

Eon	Periods	Epochs	Formational Equivalents (Approximate)
Trilobiteon	7. Phillipsian	Cameratus	Coal measures.
		Increbescens	Kaskaskia, St. Louis.
		Logani	Keokuk, Burlington.
		Marionensis	Kinderhook.
	6. Phacopsian	Disjunctus	Chemung.
		Mucronatus	Hamilton.
		Acuminatus	Corniferous.
		Arenosus	Oriskany.
		Macropleurus	Lower Helderberg.
	5. Calymenean	Vanuxemi	Waterlime, etc.
		Radiatus	Niagara, etc.
	4. Asaphian	?	Ordovician.
	3. Olenian	?	Cambrian.
	2. Paradoxidean		
	1. Olenellian		

Applying the principles set forth in this paper, a tentative table may be constructed which will express concretely what is meant by a biochronic classification and nomenclature. In this table the attempt is made to find names of genera of Trilobites for the periods of that eon in which Trilobites constitute a characteristic feature. The genera chosen actually do lap over each other in several places, but it is doubtful if any genera could be chosen which, if they did not lap over in their chronologic range, would leave actual gaps not represented in any division of the scale. The genus *Spirifer* is selected in the upper divisions of the scale, as furnishing a convenient set of diagnostic species; they, too, do not in every case avoid lapping, a difficulty which it has already been said is unavoidable when the means of measurement are multiple and not mutually exclusive. The foregoing table is offered, then, as a means of illustrating the proposed plan.

HENRY SHALER WILLIAMS.

NEW HAVEN, CONN.

VARIATIONS OF TEXTURE IN CERTAIN TERTIARY IGNEOUS ROCKS OF THE GREAT BASIN.[1]

INTRODUCTION.

DURING the field work of the writer in the Great Basin, in 1899, he found in a number of localities, chiefly near the edge of the Sierras, cases of what seemed at first extraordinary transitions or intimate alternations of texture in the Tertiary igneous rocks, which are for the most part extrusive. Microscopic and comparative examination in the office corroborated the field conclusions and showed also that the transitions were not as abrupt as they seemed at first, but were more gradual; and the study of the conditions of crystallization which may be inferred from the structure of the different varieties shows that similar conditions must exist in many other places and similar transitions may be looked for. It is true that there are in that portion of the Great Basin especially under consideration (namely, the district lying within fifty miles of Carson) exceptionally favorable circumstances for the exposure of both the surface portions and the originally deeply buried portions of lavas. The region is an arid one, and therefore the general erosion is slight; nevertheless, waters derived from the moister Sierras reach out into this region in the form of streams, and have accomplished much special or basal[2] erosion. There are also a number of lakes, which in former times were much more extensive, and probably existed in one stage or another since early Tertiary times; and the basal erosion of these lakes has probably been considerable.

Some of the special localities where the observations were made will now be described in detail.

---

[1] Published by permission of the director of the United States Geological Survey.

[2] *I. e.*, Erosion which works at the base of topographic features, undercutting them.

ANDESITIC ROCKS.

MASON'S BUTTE.

Field description.—Mason's Butte lies close to Walker River, in Mason Valley, about four miles due south from Wabuska. It is thus situated midway between the northern end of the Walker River range and the northern end of the Smith Valley and Pinenut ranges. The rocks of the butte are related to those of all these ranges, as will be shown later. The butte itself is about a mile and a half long in a northeasterly direction, and about half a mile wide. It presents from a little distance the appearance of typical volcanic rock, being distinctly thinly bedded, with red and gray zones. On the western face of the butte is a scarp two or three hundred feet high, and from here easterly there are a series of saw teeth, caused by the unequal erosion of the bands of which it is composed; then the butte sinks gradually into the plain again. The bands of igneous rock dip easterly 15° at the western end of the butte, and the dip increases to the east, so that on the eastern end they dip 30°. Here they are locally reversed and dip west, probably from movement subsequent to the eruption, which movement is also evidenced by shearing. The beds strike parallel with the longest extension of the butte (see Fig. 1).

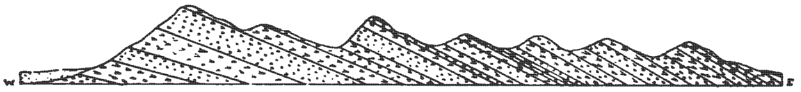


FIG. 1.—Cross section of Mason Butte, showing alternations of course and fine textured dioritic beds. Drawn to scale. Scale, 1 inch=850 feet.

Upon examination, the rocks are found to be diorite and andesite in alternating conformable layers. Fourteen different layers of diorite were found in the half-mile section, with layers of diorite porphyry and andesite between. From a structural point of view, all these rocks grade into one another. Sometimes the gradation may be actually seen in a single bed; for example, a highly porphyritic andesite, which in the field was taken for a diorite porphyry, was found to change gradually into a coarsely crystalline diorite; but generally the beds are separate. The coarse-grained rock contains some dark inclusions, which appear to be like the finer-grained rocks. The diorite is also associated with alaskite[1] which occurs in many large segregated masses irregularly distributed, and with a few quartz veins, also segregational. The alaskite and quartz veins are found only in the diorite; never in the fine-grained rocks. At the eastern end of the butte, also associated with the diorite, are considerable masses of hornblendite which grade into normal diorite.

Although a careful search was made, no intrusive phenomena showing that the andesites are intrusive into the interbedded diorites, or vice versa, were found. Although the whole butte is of rugged rock and entirely free from any vegetation sufficient to obscure exposures, yet the succession of the different beds is as normal and regular as in the case of sediments. The andesites are evidently similar to the Tertiary andesites which occur plentifully in the whole region round about. The conclusion reached in the field, therefore, was that Mason's Butte represents the roots of old volcanic flows, that the apparent bedding is a flow structure on a large scale, and that the coarse-grained and fine-grained rocks, the diorites and andesites, are different forms of crystallization from a single magma. Some of the fine-grained rocks are separate layers from the coarse-grained ones, while some are simply variations in them. The diorite naturally incloses portions of an earlier formed crust, which is identical with the finer-grained beds.

Microscopic evidence.—The structure and composition of typical specimens from this butte will now be described:

Hornblende-biotite-quartz-diorite[2] (117 N.).—This rock in the hand specimen is medium coarse granular and rather dark, on account of a liberal percentage of ferromagnesian minerals. It has the appearance of a typical granular rock. Under the microscope the structure is coarse. The largest grains are as much as 8^{mm} in diameter, and these grains, which have hypidiomorphic or idiomorphic outlines, are closely intergrown. Filling the spaces left by the intergrowth of these larger grains is a somewhat scanty mesostasis, composed of grains averaging about 1^{mm} in diameter. The minerals of the larger and the smaller grains are the same, consisting of feldspar, which is greatly in excess, and quartz, green hornblende, and biotite. The quartz is distinctly subordinate in amount to the feldspar. The feldspars were tested by the Fouqué method and gave, on sections perpendicular to both the positive and the negative bisectrices, the extinction angles for oligoclase.

---

[1] See *Am. Geol.*, April, 1900, p. 230. *Alaskite* is proposed as a general name for rocks consisting of quartz and alkali feldspars without essential ferromagnesian constituents.

[2] These numbers refer to the specimens in the writer's collection, and are given for the purposes of subsequent identification.

Hornblende-biotite-quartz-diorite (123 N.).—This does not differ in the hand specimen to any noticeable extent from 117 N. Under the microscope also the two are essentially alike, but with a slight difference. In 123 N. the larger crystals are more abundant, so that the structure at first sight appears to be coarse allotriomorphic granular. On closer analysis the section is seen to be made up of more or less idiomorphic crystals of feldspar, green hornblende, and biotite, closely packed together, with the spaces between filled with a scanty mesostasis of quartz, feldspar, hornblende, and biotite, these grains being of all sizes, commencing with the size of the idiomorphic grains just described. In this section, as in 117 N., the quartz is a subordinate essential. The feldspar, tested twice by the Fouqué method, gives the angles for andesine-oligoclase.

Hornblende-andesite (116 N.).—This is a porphyritic rock with an abundant, greenish groundmass, and is entirely similar in appearance to the hornblende-andesites of the Pinenut range, just west of the butte. Under the microscope the groundmass is found to be holocrystalline and microgranular, consisting chiefly of allotriomorphic feldspar and hornblende. The phenocrysts reach a diameter of about 2.75^{mm}, and consist of feldspar and green hornblende. The feldspars, when tested, gave twice the extinction angles of andesine. In this section the phenocrysts are less in amount than the groundmass.

Hornblende-andesite (118 N.).—In the hand specimen this has the appearance of a diorite closely verging upon diorite porphyry. Under the microscope, however, there is found to be, between the closely packed phenocrysts, a micro-granular groundmass, slightly finer grained than that of 116 N. It consists chiefly of feldspar with some hornblende. The phenocrysts also are chiefly feldspar, with subordinate hornblende, which is largely altered to epidote. Determinations of the feldspar show that it is oligoclase. The larger phenocrysts have an average diameter of about 2^{mm}.

Hornblende-quartz-andesite (121 N.).—This rock is similar in appearance to 118 N. It has also a fine holocrystalline granular groundmass, showing no fluxional arrangement and composed of feldspar and quartz. The phenocrysts have a maximum diameter of about 3^{mm}, and consist of feldspar, green hornblende, and subordinate quartz, the last named in large rounded or corroded crystals. The hornblende is largely altered to epidote. The feldspar, tested twice by the Fouqué method, shows the extinction angles of andesine and andesine-oligoclase.

Hornblende-quartz-andesite (120 N.).—This rock in the hand specimen is dense, greenish and fine grained, having a trap-like appearance, with small phenocrysts in an aphanitic groundmass. Under the microscope the rock is seen to be much like those just described. The groundmass is fine holocrystalline, consisting of lath-shaped feldspars and hornblende, with subordinate quartz and some pyrite and siderite. There is a slight fluxional arrangement. The phenocrysts belong to a distinct generation from the groundmass (*i. e.*, there are no transitions) and consist of feldspar, pale green hornblende, and a single large grain of corroded quartz. The phenocrysts reach a diameter of 2^{mm}. The hornblende is largely altered to calcite, chlorite, and epidote.

Hornblende-andesite (119 N.).—This is from the same bed as 120 N., and is simply a variation from it. In appearance it is somewhat different, on account of the more abundant conspicuous feldspar phenocrysts, which are, however, very small, so that the rock resembles a miniature of 121 N., reduced three or four times. Under the microscope the groundmass is seen to have been originally glassy, but now is devitrified, and has a cryptocrystalline structure, The phenocrysts attain a diameter of about 1^{mm}, and consist of feldspar and hornblende. The feldspar, upon optical examination, proves to be oligoclase. The hornblende is mostly altered to calcite and chlorite.

Alaskite (114 N.).—This in the hand specimen is a typical, rather fine-grained, dense rock. Under the microscope the structure is hypidiomorphic granular. The grains average 1^{mm} in diameter, and consist of quartz, orthoclase, and microcline in somewhat equal proportions. The only dark minerals present are a few grains of chlorite and pyrite.

Hornblendite (124 N.).—This is a coarse-grained rock, typical of its kind, and also consists of green hornblende, with blotches of epidote. Under the microscope the structure is seen to be allotriomorphic. No other minerals are present save those mentioned, and the epidote is secondary to the hornblende. In the section studied the grains average about 3^{mm} in diameter.

Analysis of structure.—The series of rocks just described, from 117 N. to 119 N., inclusive, shows a transition, which has at one end a typical coarse granular rock and at the other a porphyritic rock with a glassy groundmass. In the intermediate stages the phenocrysts increase in numbers and somewhat in size, while the groundmass shrinks in volume and becomes also coarser. In 123 N., which is a typical granular rock only slightly removed from 117 N., these phenocrysts have increased until they nearly fill the rock, while the small portion of groundmass which remains has coarsened so that the grains are a millimeter in diameter; thus the rock at first sight appears a typical allotriomorphic granular rock, from which it is moreover not far removed.

The very slight variations of structure between any two adjacent members of this transition series shows that the differences in condition which brought about the separation of the coarse-grained from the fine-grained rocks were relatively small. These differences are plainly longer cooling periods (and hence longer crystallization intervals) in some portions of the rock, as compared with others. The coarse granular rocks, judging from their almost complete and uniform crystallization, have crystallized entirely in their present position; the segregation from them of alaskite on the one hand, and hornblendite on the other, is additional evidence of this. The porphyritic forms, however, show generally two distinct generations, and this, with the fact that some of the phenocrysts of the first generation, especially the quartz, show corrosion and resorbtion, indicates a change of conditions; also the slight fluxional arrangement, sometimes observed, shows at least local movement. Yet the contemporaneity of the fine-grained porphyritic rocks with the granular forms, shows that the crystallization break registered by the former did not arise from any important change of position.

Composition of rocks.—The general mineral composition of rocks of all structures (leaving out the alaskite and hornblendite, which are plainly segregation products from the hornblende quartz-diorite), is the same, being a hornblende-quartz-diorite or quartz-andesite. In the andesites the quartz, where present, was plainly in process of resorbtion by the groundmass at the time of solidification, so that it is probable (from the fact the hornblende andesites and the hornblende-quartz-andesites often occur as variations of a single bed) that in those andesites which do not show free quartz the composition is the same as where they do, the quartz belonging to the first period of crystallization having been entirely resorbed.

Analyses of the rocks are as follows (analyst, Dr. H. N. Stokes):

No. 1, No. 117 N. Hornblende-biotite-quartz-diorite		No. 2, No. 120 N. Hornblende-quartz-andesite	
SiO_2	60.25	SiO_2	53.37
Al_2O_3	17.90	Al_2O_3	16.57
Fe_2O_3	3.08	Fe_2O_3	3.84
FeO	2.44	FeO	2.45
MgO	2.44	MgO	5.79
CaO	5.57	CaO	6.30
Na_2O	4.29	Na_2O	3.40
K_2O	1.89	K_2O	2.55
H_2O+	.20	H_2O+	.39
H_2O	1.24	H_2O	2.33
TiO_2	.65	TiO_2	.86
CO_2	none	CO_2	1.61
P_2O_5	.25	P_2O_5	.29
MnO	.06	MnO	.08
SrO	.07	SrO	trace
	100.33		99.83

In No. 1 the ratio of $Na_2O + K_2O : CaO = 1 : 1.1$. In No. 2 the same ratio is $1 : 1.13$. These ratios are calculated from the quotient figures obtained by dividing the percentages of each by the molecular weights. Similarly in No. 1 the ratio of $K_2O : CaO$ is $1 : 4.95$. In No. 2 the same ratio is $1 : 4.18$.

No. 2 contains less quartz and more hornblende than No. 1, hence the decrease in silica and the increase in magnesia; otherwise the two rocks are the same.

Correlation of rocks.—As before stated, just west of Mason's Butte lies the northern end of the Smith Valley and Pinenut ranges. On crossing from Waubuska through Churchill Canyon, andesites were found which were recognized in the field as similar to those in the butte. The bedding of these rocks is nearly horizontal. They are fine-grained hornblende-andesites, often with fine holocrystalline groundmass; occasionally they vary to fine-grained diorite porphry. In higher portions of the mountains (these relatively coarse-grained lavas are exposed in the lowest cuts) the lavas are dacites and pyroxene andesites.

Andesites form the main mass of the Pinenut range at its northern end, which is separated from the Washoe district at the southern end of the Virginia range by a comparatively narrow valley. The lavas of one range are evidently continuous with those of the other.[1] In the Washoe district have been found eruptions of hornblende-mica-andesite and quartz-andesite or dacite, corresponding exactly to that at Mason Butte. At Washoe, also, the andesite becomes, under favorable conditions, coarsely crystalline, and Messrs. Hague and Iddings[2] have noted that upon this complete crystallization quartz separates out, producing a mica-quartz-diorite.

RHYOLITIC ROCKS.

TRANSITIONS IN TEXTURE OF THE BASAL RHYOLITES OF THE PINENUT RANGE.

Field description.—The central core of the Pinenut range is made up of granitic rocks. These were examined in two localities: one southeast from Dayton, and one west from Wellington.

At the first mentioned locality, granitic rocks are exposed along an easterly facing scarp which is at the north end of Smith Valley. The rocks are all granular, so far as observed, but vary much in texture from fine to coarse; they are often porphyritic. They show a distinct banding, resembling at a distance rude stratification; this banding is due to a zonal arrangement of the rocks of different textures.

In the district west from Wellington, rhyolitie and granitic rocks are exposed in the spur just east from the Mountain House, and are of exceptional interest. Here, beneath the andesitic rocks which cover the mountain slopes, is found a highly indurated volcanic conglomerate and sandstone, apparently waterlaid, and consisting entirely of rhyolitic material. A short distance farther on, the rocks from which these detritals are derived were found in place. These original rocks show great variations, passing from a fine-grained, almost aphanitic, rhyolite, to coarse siliceous granite and alaskite. The numberless variations are within a few feet of one another and are arranged in bands, recalling immediately the similar phenomenon in the andesitic rocks of Mason Butte. In the case of the rhyolitic rocks also there is no sign of intrusion of one into another, nor in general does there appear to be any marked gradations between the different bands at contact, the boundaries between them being fairly distinct.

---

[1] See "The Succession and Relation of Tertiary Igneous Rocks in the Great Basin Region," JOUR. GEOL., Vol. VIII, p. 621.

[2] Bull. 17, U. S. Geol. Surv.

It is clear in the field that the variations are chiefly textural and that the composition of all the varieties is nearly the same — that of siliceous granite or rhyolite.

In this case again, we have rocks which appear to represent the roots of old volcanics, being intermediate between completely massive plutonic igneous rocks and superficial fine-grained volcanics. They must have suffered a flowage resulting in the formation of this peculiar streaky structure, while the great variations in texture in the different bands show crystallization at points still far removed from the surface.

Of the different rock varieties in the locality west from Wellington the following will be briefly described.

Biotite-rhyolite (164 N^{a}.).—Structure porphyritic; groundmass cryptocrystalline, probably devitrified glass. The phenocrysts are of all sizes, the larger ones grading down to those which vanish in the groundmass. They are of feldspar, quartz, and biotite, the latter decomposed. The feldspar was determined to be largely albite and oligoclase-albite, although there is some orthoclase, The largest phenocryst of feldspar measures 2¾^{mm} in diameter; the largest one of the quartz, 1⅛^{mm}. The rock contains angular fragments of finer grain. Some of these seem to be devitrified rhyolitic glass, while others are fragments of more basic lava, probably andesite — these latter show small lath-shaped feldspar phenocrysts in a glassy semi-devitrified groundmass.

Biotite-rhyolite (165 N^{a}.).—In this specimen the groundmass becomes slightly coarser than in the preceding specimen and is very fine microgranular. It also becomes more scant than in

164 N^a, on account of the multiplication of phenocrysts, which show the same great variety in point of size as the rock just described. The same angular fragments of more basic lava also occur. The phenocrysts are quartz, orthoclase, and a striated feldspar; the latter tested twice by the Fouqué method proves to be albite. The orthoclase was optically determined as such.

Rhoylite (162 N^a.).—In this rock the groundmass is fine holocrystalline, coarse enough to enable one to distinguish the mosaic of quartz and feldspar. This groundmass contains the same fragments of more basic lava that have already been described, and also encloses broken phenocrysts of mostly unstriated feldspar.

Granite-porphyry, fine-grained (169 N.).—In this rock the groundmass is fine granular, sometimes granophyric, and conrists chiefly of quartz and orthoclase. The phenocrysts are abundant and consist of quartz and feldspar, with chlorite and epidote which are derived from the decomposition of ferromagnesian minerals. The feldspar phenocrysts are partly orthoclase and partly a striated feldspar, which, determined by the Foqué method, proves to be oligoclase-albite.

Biotite-granite, medium-grained (171 N.).—In this rock the grains are of two distincts sizes, one many times larger than the other. The larger grains have a tendency to idiomorphism, the smaller grains to allotriomorphism. The smaller grains are included between the interlocking larger ones and may be considered as forming an overgrown groundmass, partly crowded out by the multiplication and joining of phenocrysts, which are represented by the larger grains. The minerals of the rock are quartz, feldspar, biotite, and magnetite. The feldspar is almost entirely orthoclase, with some microcline and albite.

Granite, coarse (175 N.).—The structure of this rock is like that of the preceding, only coarser. It contains many perfect idiomorphic crystals of feldspar, often touching and almost interlocking, and smaller crystals of bleaching biotite and ragged pale green hornblende, the last perhaps secondary. These minerals are in general cemented by a mesostasis of coarse allotriomorphic quartz, which often includes or is intergrown with, in poikilitic fashion, smaller crystals of feldspar, pale green hornblende, and sphene. The feldspar included in the quartz sinks to very small dimensions, whereas the ordinary feldspar grain is very large. The structure may be regarded as the coarsening of the porphyritic structure, or at least closely related to it by reason of the two generations. The large feldspar crystals are partly orthoclase, but are chiefly finely striated. Optical determinations of the striated crystals show microcline-anorthoclase and albite.

Granite, coarse (172 N.).—This rock is almost entirely like 175 N, and has a good deal of the peculiar structure of this rock, but in general is more hypidiomorphic granular or truly granitic.

Analysis of the structures of the granite-rhyolites.—The analysis of the structure of the granites and rhyolites just described helps toward a better understanding of their relation.

164 N (a). Here are phenocrysts of all sizes, gradually shrinking in size to the glassy (sometimes slightly devitrified) groundmass; *i. e.*, the crystallization, instead of belonging to one or two distinct generations, represents many generations, not separable from one another. This is a proof of gradual and equable hardening. It shows that the viscosity increased very slowly and regularly to the point of final complete solidification, the newer crystals having progressively smaller fields of crystallization.

165 N(a). This is like 164 N(a) except that the groundmass diminishes, on account of multiplication of phenocrysts. This marks a longer cooling period than 164 N(a), so long as almost to permit of total crystallization as relatively large crystals.

162 N(a). In this section the feldspar phenocrysts are not connected by gradual transitions with the groundmass, which is slightly coarser than that of 165 N(a) and is much more abundant. We have, therefore, two distinct generations of crystallization, and this, together with the frequently broken character

of the phenocrysts, indicates a break in the crystallization, evidently resultant from a movement of the solidifying mass. The order of events in this section was, therefore, (1) comparatively slow crystallization of feldspar; (2) flowage, producing a change of conditions; (3) medium rapid cooling, bringing about the uniform moderately fine crystallization of the rest of the rock.

169 N. Here the line between the abundant phenocrysts and the fine-grained groundmass is, in general, distinct, for although there are transitions between the two they are not so abundant as in rocks like 164 N(a) and 165 N(a). This connotes a shorter period of first crystallization (when the phenocrysts were formed) than does 165 N(a), then a more rapid cooling than 165 N(a) to a certain point, then a slower rate of crystallization, permitting the formation of the uniform fine granular structure.

171 N. The structure of this connotes a long period of slight viscosity, during which the crystals of quartz and feldspar could grow until they touched and sometimes interlocked. The difference in size between these crystals and the grains of the groundmass or mesostasis which fills the space between them, implies a slight break or change of conditions, after which was again a comparatively slow uniform crystallization of the rest of the rock, producing an even allotriomorphic granular structure. There are then two distinct generations of crystals. The resulting structure is entirely similar to the ophitic structure of diabases, save that in these siliceous feldspars the forms are not so elongated, and so the structure is not so striking. The structure of this specimen, however, differs from the typical granitic structure in the same way that a diabase differs in structure from a gabbro. A longer period for the first crystallization, reducing the mesostasis to a still smaller percentage, would give the aplitic structure, where the idiomorphic crystals are predominant and occupy the greater portion of the section.

175 N. This is like 171 N, but in general the mesostasis of comparatively small grains is wanting, being replaced by a filling of coarse allotriomorphic quartz. In this case the conditions of crystallization have evidently been gradual throughout. The

rock crystallized slowly under conditions of slight viscosity. After the exhaustion of the feldspathic material residual quartz crystallized in the remaining spaces.

Tabulation.—The following table shows the gradation from fine-grained rhyolite to granite:

Specimen No.	Character of groundmass.
164 N (a)	Glassy.
165 N (a)	Cryptocrystalline.
162 N (a)	Finely microgranular.
169 N	Microgranular; micropegmatic.
171 N	Granular; grains average $.5^{mm}$ diameter.
172 N	Granular; grains average $.5^{mm}$ diameter.
175 N	Large quartz grains, average 2.25^{mm}.

Analyses.—The following are analyses of the two fairly typical specimens as above described (analyst, Dr. H. N. Stokes):

(1) 168 N. Biotite rhyolite. Like 165 N (a).		(2) 172 N. Siliceous granite.	
SiO_2	71.49	SiO_2	75.09
Al_2O_3	15.06	Al_2O_3	13.51
Fe_2O_3	1.51	Fe_2O_3	1.13
FeO	.88	FeO	.08
MgO	.35	MgO	.18
CaO	1.54	CaO	.91
Na_2O	4.19	Na_2O	3.58
K_2O	3.39	K_2O	4.71
H_2O-	.16	H_2O-	.17
H_2O+	.88	H_2O+	.25
TiO_2	.20	TiO_2	.22
CO_2	none	Co_2	none
P_2O_5	.08	P_2O_5	.04
MnO	trace	MnO	trace
SrO	trace	SrO	trace
	99.73		99.87

It will be seen that No 2 is slightly more siliceous than No. 1; nevertheless the two rocks are intimately related. In No. 1 the relation of $K_2O + Na_2O : CaO = 1 : .26$. In No. 2 the same ratio equals $1 : .15$. Similarly, in No. 1 the relation of $K_2O : CaO = 1 : .75$. In No. 2 the same ratio equals $1 : .32$.

Conclusions.—Many of the bands in this granite-rhyolite series show by their structure that they have undergone no break in crystallization from beginning to end. The rocks have evidently crystallized entirely in their present position, and the slow hardening which is ordinarily indicated shows that this point of consolidation was originally some distance from the surface.

In other specimens there have been slight breaks, bringing about two, three, or more generations of crystals which in the rocks near by are not distinguishable. These minor breaks were due to slight migrations of material in certain bands, which flowed slightly during the process of cooling, as is proved by the angular fragments of finer-grained lava which they contain and by the occasional broken condition of the phenocrysts.

As explanation of the difference in crystallization between the granular bands and the intercalated fine-grained ones, it must be remembered that those bands which were affected by flowage must have been at the time those possessing least viscosity and consequently those which were least crystallized. The final crystallization of these bands, therefore, took place at a later period than that of granular bands, at which period the rate of solidification was very likely more rapid. It is probable, moreover, that the movement of flowage brought on of itself a more rapid crystallization than if the rock had been undisturbed, and that thus the finer-grained groundmass orginated. The same suggestions hold good for the similar phenomena, already described at Mason Butte.[1]

---

[1] In connection with the conclusion above arrived at, *i. e.*, that the phenocrysts of the rocks were formed practically in place, compare the papers by Professor Pirsson and Professor Crosby. (*Am. Jour. of Sci.*, Vol. VIII, April, 1899, p. 271, "On the Phenocrysts of Intrusive Igneous Rocks," and *American Geologist*, Vol. XXV, No. 5, May, 1900, "On the Origin of Phenocrysts and the Development of Porphyritic Texture in Igneous Rocks.")

Professor Pirsson argues that the phenocrysts of intrusive rocks are not necessarily intratelluric, and that there is no necessity of more than one period of crystallization even for porphyritic rocks. From the fact that contact zones are often without phenocrysts, while the rest of the rock contains them; that in a contemporaneous complex of dikes and sheets some may have phenocrysts while others do not; from observed cases where fluidal phenomena show that phenocrysts have developed after the flowage; from the arrangement of the crystals of the groundmass around some phenocrysts, showing that these crystals have been crowded and shoved during the growth of the larger crystals; and from the fact that many granites (which have generally been considered intratelluric) contain very large phenocrysts, Professor Pirsson

TRANSITIONS OF TEXTURE IN THE GRANITE-RHYOLITES OF THE QUINN CANYON RANGE.

Field description.—The Quinn Canyon range lies a long distance east of all the other localities which have been described, being almost due south from Eureka and nearly west of Pioche. The whole southern portion of the range is buried in rhyolitic flows.[1] The range was examined by the writer at its northern end, where the Paleozoic core of the mountains emerge from the volcanic covering. On the western side of the range, near the contact of the Paleozoics with the rhyolite, the stratified rocks are pierced by numerous great dikes, which vary from coarse to fine in texture. These dike rocks seem similar in composition, and sometimes in texture, to the rather massive rhyolite which forms the hills to the west of this locality.

Microscopic description.—A specimen of the main rhyolite examined under the microscope has the following characteristics:

Rhyolite (241 N.).—This rock has phenocrysts of all sizes,

reasons that phenocrysts are not necessarily of a distinct crystallization period as compared with the groundmass, but may in some cases be formed in place. Professor Pirsson advances the explanation that a comparatively rapid fall of temperature and decrease of hydration, resulting in a viscosity augmenting in an increasing ratio, may produce monogenetic phenocrysts (that is, phenocrysts which occur only in a single generation). Recurrent phenocrysts (that is, those occurring in more than one generation) he explains as due to mass action, believing that minerals which are present in very large quantity are especially active crystallizers.

Professor Crosby believes that no sudden changes of temperature, hydration, or pressure, are necessary for the formation of phenocrysts. He believes that in a gradually consolidating rock the crystallization first established may be brought to a close by the gradually increasing viscosity and that after passing this critical point new zones of crystallization will be established, of much smaller field, and at this point the groundmass begins and the phenocrysts end. If the rate of cooling is still slower, an allotriomorphic granular texture results, while if the rate is more rapid the texture may be glassy or nearly so.

The deductions of the writer, given above, agree with those of the authors cited in this, that phenocrysts may be formed in place. His observations, however, go to show that where cooling is strictly uniform there will be no distinct generations, but a gradual transition from phenocrysts to groundmass; whereas, if there are distinct generations, they are brought about by breaks in the conditions of consolidation, even though these breaks be comparatively slight.

[1] G. K. GILBERT, *Survey West of the 100th Meridian*; Vol. III, Geology, p. 122.

from $1\frac{1}{2}^{\mathrm{mm}}$ in diameter grading down into groundmass, which is cryptocrystalline, probably a devitrified glass.

Two selected specimens of the dike rocks have the following characteristics:

Biotite-granite-porphyry, near rhyolite (243 N.).—Like 241 N, this rock has phenocrysts of all sizes, from $1\frac{1}{2}^{\mathrm{mm}}$ in diameter down to the groundmass. There are, however, more phenocrysts in this rock than in the one just described. As in 241 N, the phenocrysts have no fluxional arrangements, but a divergent one. The groundmass is fine holocrystalline allotriomorphic ganular.

Biotite-granite (242 N.).—This rock consists of grains of all sizes from $6\frac{1}{2}^{\mathrm{mm}}$ in diameter down to the very minutest dimensions. The smallest ones, which are very abundant, are about .02 to $.03^{\mathrm{mm}}$ in diameter. There is a tendency to idiomorphism throughout. The smaller sizes of crystals act as mesostasis for the larger ones, and these have a mesostasis of the still smaller ones. The essential minerals are quartz, othoclase, and biotite, with accessory hornblende, titanite, magnetite, and a little striated feldspar.

Analyses.—The chemical composition of these rocks is as follows (analyst, Dr. H. N. Stokes):

(1) No. 214 N, Siliceous Rhyolite.		(2) No. 242 N, Biotite Granite.	
SiO_2	74.67	SiO_2	71.48
Al_2O_3	13.25	Al_2O_3	13.00
Fe_2O_3	1.06	Fe_2O_3	1.25
FeO	.18	FeO	1.55
MgO	trace	MgO	.95
CaO	1.26	CaO	2.60
Na_2O	3.99	Na_2O	2.60
K_2O	4.62	K_2O	4.24
H_2O-	.18	H_2O-	.20
H_2O+	.22	H_2O+	1.24
TiO_2	.07	TiO_2	.43
CO_2	.79	CO_2	.30
P_2O_5	.06	P_2O_5	.09
S	trace	S	none
MnO	none	MnO	.09
BaO	none	BaO	.09
SrO	none		
	100.35		100.11

In No. 1 the relation $K_2O + Na_2O : CaO = 1 : .2$. In No. 2 the same relation equals 1 : .53. In the same way, in No. 1, $K_2O : CaO = 1 : .46$. In No. 2 the same ratio equals 1 : 1.

Conclusions.—In the field the evident relation of the dikes to the rhyolite led to the inference that they had been the feeders of the extrusive rock. Under the microscope the composition of the three rocks is found to be the same, and the structure shows variations indicating no great differences in the conditions of cooling. The structure is identical with that of certain specimens of rhyolite-granite just described from the Pinenut range, and therefore need not be analyzed again. Briefly, in all three it indicates complete crystallization in one place, with no interrupting movement. The period of consolidation for 241 N was comparatively short, that of 243 N somewhat longer, and that of 242 N markedly greater than 243 N.

ANALOGOUS CASES OF VARIATIONS OF TEXTURE IN OTHER PARTS OF THE GREAT BASIN.

In the Washoe district, Nevada, not far from the first locality decribed by the writer, Messrs. Hague and Iddings[1] found a gradual transition from pyroxene andesites with glassy groundmass to pyroxene-diabase with coarse granular structure. In the Sutro Tunnel they found coarsening of the crystallization as the tunnel nears the core of Mount Davidson, so that at one end the rock may be called andesite and at the other end diabase. They also discovered like transitions between andesite and granular diorites.

Similarly they found that the earlier hornblende-andesite passes into diorite, while the later hornblende-mica-andesite changes into mica-diorite in such a way that the two rocks are inseparable. They concluded that a dike of so-called diabase is a variation of the basalt, which was one of the latest extrusions.

In short, according to these writers, the coarse holocrystalline rocks of the Washoe district are chiefly Tertiary, and are partly extrusive and partly closely connected with extrusives of similar composition. Another interesting conclusion is that the change between the lava texture and the granitoid texture consists chiefly in the coarsening of the groundmass.

---

[1] Bull. 17, U. S. Geol. Surv.

In 1899, Messrs. Tower and Smith described textural transitions in the Tintic range in Utah, which lies within the petrographic province of the Great Basin and is situated southward from Great Salt Lake.[1] In this district is found pyroxene andesite or perhaps more properly latite, which is an effusive rock and is closely associated with granular monzonite. There are all variations of texture between andesite with glassy groundmass to that with a holocrystalline groundmass; from this to closely similar rocks, also with holocrystalline groundmass, which are called monzonite porphyry; and from these through panidiomorphic granular phases to those of hypidiomorphic granular structure.

CONCLUSIONS.

In the Great Basin, particularly in Nevada, we have Tertiary extrusive rocks which show transitions from a granular structure with glassy groundmass. The different phases are often intimately associated, and structural analysis shows that the differences of crystallization which brought about these variations were slight, a relatively small decrease of the rate of cooling being sufficient to allow the formation of the holocrystalline instead of the porphyritic structure.

Transitions similar to those found in the Great Basin have been sparingly chronicled elsewhere. These appear to become rare in proportion as the rocks become siliceous. This is so because with a given relatively rapid rate of cooling a magma of basic composition will consolidate with a holocrystalline structure, while a siliceous magma will become fine-grained and porphyritic. We have accordingly many instances of holocrystalline diabases which are certainly extrusive, and of similar rocks in rather fresher condition (generally due to their being younger) which have been called dolerites. In the more siliceous rocks such textural transitions are rare in effusive bodies, but further down, at the roots of volcanoes, the conditions are such as to allow viscosity to increase with the same slowness that it does with a more rapid cooling rate in more basic rocks. Hence with increasing acidity we find the coarser grained varieties further removed from the surface. In general, however, it is plain that a granular rock is not necessarily a deep-seated one, in the formerly accepted sense of the word.

---

[1] *Nineteenth Ann. Rept. U. S. Geol. Surv.*, p. 656.

Another conclusion which may be made from the foregoing studies is, that the more important structures are not peculiar to particular rocks. The porphyritic and the coarse granular allotriomorphic or hypidiomorphic structures are already recognized as characterizing all rocks, of whatever chemical composition. Also the aplitic structure, or that in which idiomorphic minerals (which are the same as the phenocrysts of the porphyries) form the greater bulk of the rock, has been recognized as universal by Rosenbusch, who has described it in granitic rocks and in all intermediate ones down to gabbros; thus his rock terms include syenite aplite and gabbro aplite. The ophitic structure has been generally supposed to be characteristic of diabases, and without question is here best exhibited, on account of the rate of solidification which the basic composition of a magma entails and also because the elongated forms of the basic feldspars make the structure prominent. The foregoing studies, however, show that this structure is intermediate between the porphyritic and the aplitic structures, representing a stage in crystallization when the idiomorphic crystals (or phenocrysts, as they are called in the porphyries) have multiplied and grown so that they interlock; and that like these other structures it may occur in any rock. In the granites it is not so striking as in more basic rocks, on account of the blunt form of the alkaline feldspars which form the first generation of crystals, but it is nevertheless present in some of the granites which have been studied. In diorites the ophitic structure has been occasionally described.[1]

---

[1] ROSENBUSCH, *op. cit.*, p. 256; ZIRKEL, *Lehrbuch der Petrographie*, 2d ed., p. 483.

The writer, of course, interprets the term ophitic in its broader and not in its narrower sense, accepting it as meaning a structure where a network of interlocking, divergent, comparatively large feldspar crystals is filled in by grains of much smaller dimensions, whatever the nature of these grains may be. He does not interpret it as meaning that the mesostasis is necessarily augite. He finds grounds for this broader acceptation in the writings of Rosenbusch, Zirkel, and others. Rosenbusch applies the term ophitic[1] to diabases where the mesostasis is not augite, but an aggregate of primary quartz and feldspar.

Therefore, the glassy, fine porphyritic, coarse porphyritic, ophitic, aplitic and hypidiomorphic granular structures may occur in any rocks. They pass by gradual transitions into one another and are dependent upon relatively very slight differences in conditions of cooling. All may be formed without any marked migration of the consolidating rock.

These conclusions are important in considering rock classification, as showing that structure cannot be made the element of greatest importance. Granites, granite porphyries, granite aplites and rhyolites, for example, must not be separated, but put as closely together as possible, and the same is true of diabases, diabase porphyrites, diabase aplites, and basalts.

J. E. SPURR.

[1] *Mikroskopische Physiographie*, 3d ed., p. 1117.

THE FOYAITE-IJOLITE SERIES OF MAGNET COVE: A CHEMICAL STUDY IN DIFFERENTIATION.

INTRODUCTORY.

SOMETIME since I published a paper[1] on the "Igneous Complex of Magnet Cove," in which it was shown that the main types found there were arranged in a very regular series from the center to the periphery of the mass, and that this was an excellent example of the differentiation of a magma in place, presenting, however, the anomaly of being less "basic" at the borders than at the center. It was also remarked that the analyses then available "vary continuously in one direction, with scarcely a break or abnormality of any kind."[2]

Since then several considerations led to the belief that a new and more detailed chemical examination of the main rock types was desirable. Several of these, notably the "leucite-porphyry" and ijolite, are representatives of rock groups of great theoretical importance, complete analyses of which are highly desirable. In this respect many of those published by Williams[3] are defective, the non-determinations of the rarer constituents being largely due to the fact that the importance of completeness in rock analysis was not recognized at the time they were made.[4]

Such a reëxamination seemed to be the more desirable, since in a recent paper Pirsson[5] has shown that the rocks occurring in the Little Belt Mountains of Montana form an extremely regular series. By plotting the constituent oxides on an abscissal basis of distance from the center of the mass, he arrived at the conclusion in this case that, "given the percentage of one element, the chemical composition of any rock of the series to within a fraction of 1 per cent. can be deduced from the diagram." This instance is the first in which the differentiation of a mass of magma is rendered capable of exact mathematical treatment and proof, and its great theoretical interest and importance is obvious. The conditions of the locality were such that it was thought that the Magnet Cove complex might furnish another favorable example of the same kind, a hope which was justified by the results obtained, as will be seen later.

---

[1] *Bull. Geol. Soc. Amer.*, Vol. XI, p. 389, 1900.

[2] *Op. cit.*, p. 403.

[3] J. F. WILLIAMS, "Igneous Rocks of Arkansas." *Ann. Rep. Geol. Surv. Ark.* Vol. II, 1890.

[4] *Cf.* J. C. BRANNER, in Williams, *op. cit.*, p. xiv.

[5] L. V. PIRSSON, *Twentieth Ann. Rep. U. S. Geol. Surv.*, Part II, p. 569 ff., 1900.

The analyses of six of the representative plutonic rocks of Magnet Cove, as well as two of Fourche Mountain, were therefore undertaken, with the determination of the rarer constituents which might be present. For petrographic descriptions the reader is referred to the two papers cited above.

In this connection I would express my full endorsement of Pirsson's remarks[1] on the importance of good and complete analyses, which are absolutely essential for such mathematical discussion, and with him deplore their comparative rarity. To many petrographers, any collection of figures which foots up within 98 and 102 per cent. is a usable analysis, even though the results are at variance with the mineralogical composition, and some of the obviously important constituents are not estimated. It is not realized that such "analyses" do far more harm than good to the science. From this point of view alone, the excellent work of Dr. Hillebrand and the other chemists of the United States Geological Survey is of inestimable value, as they have set a standard to fall short of which in any marked degree should be accounted a petrographic sin. Let me be the first to confess "*peccavi.*"

ANALYSES.

Pulaskite.—The specimen of this type was collected at the Little Rock Granite Company's quarry, at Fourche Mountain, near Little Rock, the type locality. In I is given my analysis, in II that of R. N. Brackett, as quoted by Williams. The two do not differ materially, I showing rather less Fe_2O_3 and CaO and more FeO, MgO, and alkalis, though the ratio of

---

[1] L. V. PIRSSON, *op. cit.*, p. 578.

	I	II		I	II
SiO_2	60.20	60.03	TiO_2.......	0.14	....
Al_2O_3......	20.40	20.76	ZrO_2.......	trace	....
Fe_2O_3	1.74	4.01	P_2O_5	0.15	0.07
FeO	1.88	0.75	SO_3.......	0.13	....
MgO........	1.04	0.80	Cl..........	0.09	....
CaO........	2.00	2.62	S..........	none	....
Na_2O.......	6.30	5.96	MnO.......	trace	trace
K_2O.......	6.07	5.48	BaO	trace	....
H_2O(110°+)	0.23	0.53			
H_2O(110°—)	0.10	0.06		100.47	101.07
C_2O........	none	....			

I. Pulaskite, Fourche Mountain. Washington, analyst.

II. Pulaskite, Fourche Mountain. Brackett, analyst. WILLIAMS, *op. cit.*, p. 70.

$Na_2O : K_2O$ is about the same in both, being 1.57 in I and 1.66 in II. The specimen analyzed by Brackett apparently contained a little more acmite, though the variations are scarcely more than are to be expected in different specimens from the same mass.

Analysis I can be calculated out as below. There is apparently an excess of Al_2O_3, amounting to about 4 per cent. in this, as well as in II, which it is difficult to account for. It does not seem to be due to kaolinite or hydronephelite, as the rock is too fresh, and there is no muscovite present. Such an excess of Al_2O_3 above $(Na_2O+K_2O) - Fe_2O_3$ may be observed in many analyses of nephelite-syenites, if the Fe_2O_3 is calculated as acmite, and no anorthite molecule is assumed to be present. Among these are some by Hillebrand, and there is no reason to suppose that this peculiarity is due to errors of analysis. It is a feature of this group of rocks which seems to call for investigation, and may possibly be connected with the occurrence of corundum in the nephelite-syenites.

Orthoclase - - - - - -	35.1
Albite - - - - - - - - -	39.8
Nephelite - - - - - - - -	3.1
Sodalite - - - - - - - -	1.2
Aegirite - - - - - - - -	5.1
Hornblende, diopside, and biotite - -	11.0
Apatite - - - - - - - -	0.5
Extra alumina - - - - - -	4.2
	100.0

Pulaskite (*Foyaite*).—This is Williams's "gray granite," the specimen coming from Braddock's quarry, on Fourche Mountain. My analysis is given in I below, with that of W. A. Noyes as quoted by Williams in II. The two are closely alike in all respects except Al_2O_3, which is about 2 per cent. higher in I, as about 1 per cent. of TiO_2, and a trace of P_2O_5 must be deducted from the Al_2O_3 of II.

	I	II		I	II
SiO_2	60.13	59.70	CO_2	none	....
Al_2O_3	20.03	18.85	TiO_2	1.15	....
Fe_2O_3	2.36	4.85	ZrO_2	0.05	....
FeO	1.33	....	P_2O_5	0.06	....
MgO	0.76	0.68	SO_3	0.14	....
CaO	0.87	1.34	MnO	trace	....
Na_2O	6.30	6.29	BaO	trace	....
K_2O	5.97	5.97			
H_2O (110°+)	1.41	1.88		100.72	99.56
H_2O (110°−)	0.16	....			

I. Pulaskite, Braddock's quarry, Fourche Mountain. Washington, analyst.
II. Pulaskite ("Foyaite"), same locality. Noyes, analyst. WILLIAMS, *op. cit.*, p. 81.

The analysis (1) calculates out as follows, and it is evident that there is no essential difference between this rock and the last mentioned.

Orthoclase	28.6
Albite	39.0
Nephelite	6.2
Nosean	1.2
Kaolin	7.5
Aegirite	6.9
Biotite	7.9
Titanite	2.7
	100.0

Foyaite.—What seemed to be an average specimen of the occurrence at Diamond Jo quarry, Magnet Cove, was chosen for analysis. No pyrite was visible, though the analysis shows a trace of sulphur. One or two small garnets were seen in one section, which mineral is not mentioned by Williams as an accessory.

Apart from the determination of minor constituents, my analysis (I) does not differ materially from that of Brackett

	I	II	I	II	
SiO_2	53.09	53.38	TiO_2	0.11	....
Al_2O_3	21.16	20.22	ZrO_2	0.04	....
Fe_2O_3	1.89	1.56	P_2O_5	0.15	....
FeO	2.04	1.99	SO_3	none	....
MgO	0.32	0.29	Cl	0.02	....
CaO	3.30	3.29	S	0.08	1.77[1]
Na_2O	6.86	7.89	MnO	0.20	trace
K_2O	8.42	6.21	BaO	0.61	....
H_2O(110°+)	1.13	3.43			
H_2O(110°−)	0.24			100.48	100.03
CO_2	0.82				

I. Foyaite, Diamond Jo quarry, Magnet Cove. Washington, analyst.
II. Foyaite, same locality. Brackett and Smith, analysts. WILLIAMS, Sp. gr. 2.599 at 26°C., *op. cit.*, p. 238.

and Smith (II), except in the presence in the latter of nearly 2 per cent. of pyrite, and in the alkalis. I gives a ratio of $Na_2O:K_2O$ of 1.3, while in II it is 1.92. The amount of BaO in I is high, and is noteworthy since it is found only in traces or not at all in the other rocks. It probably belongs with the abundant orthoclase, since other cases are known of BaO partially replacing K_2O in the feldspar of alkaline rocks. The analysis calculates out thus:

Orthoclase	51.8
Nephelite	20.3
Cancrinite	13.1
Aegirite	5.7
Diopside	8.6
Titanite and pyrite	0.5
	100.0

It is seen that this bears out Williams's remark that "the orthoclase is perfectly free from isomorphous mixtures of other feldspars." It is indeed somewhat remarkable that the albite molecule should be entirely lacking, or almost so, in a rock containing so much soda. It seems to be characteristic of the

---

[1] FeS_2.

Magnet Cove rocks that albite, as well as anorthite and hornblende, are of very limited occurrence.

Covite ("*Shonkinite*").—The specimen of this rock, which is Williams's "fine grained syenite," came from below the schoolhouse on the western border of the Cove, and the analysis was published in my former paper. It is repeated here, with the addition of P_2O_5, which has been determined since. Several analyses of analogous rocks are also given.

	I	II	III	IV	V
SiO_2	49.70	44.65	47.61	48.98	46.99
Al_2O_3	18.45	13.87	14.26	12.29	17.94
Fe_2O_3	3.39	6.06	4.90	2.88	2.56
FeO	4.32	2.94	4.07	5.77	7.56
MgO	2.32	5.15	2.62	9.19	3.22
CaO	7.91	9.57	8.71	9.65	7.85
Na_2O	5.33	5.67	6.70	2.22	6.35
K_2O	4.95	4.49	4.08	4.96	2.62
H_2O(110°+)	1.09	2.10	1.89	0.56	0.65
H_2O(110°−)	0.25	0.95	0.26	0.26	....
CO_2	....	0.11	....	....	....
TiO_2	1.33	0.95	1.38	0.98	0.94
ZrO_2	....	....	0.18	....	....
P_2O_5	0.40	1.50	1.38	0.98	0.94
SO_3	....	0.61	....	....	....
Cl	....	trace	0.37	....	....
F	....	....	trace	0.22	....
S	....	....	0 03	....	....
MnO	trace	0.17	0.30	0.08	trace
BaO	....	0.76	0.41	0.43	none
SrO	....	0.37	0.36	0.08	....
	99.44	99.99	100.68	99.99	99.60

I. Covite, Below Schoolhouse, Magnet Cove. Washington, analyst. *Bull. Geol. Soc. Amer.*, Vol. XI, p. 399, 1900.

II. Theralite, Gordon's Butte, Crazy Mountains, Montana. Hillebrand, analyst. J. E. WOLFF, *Bull. No. 150* U. S. Geol. Surv., p. 201, 1898.

III. "Tinguaite," Two Buttes, Colo. Hillebrand, analyst. *Bull. 148* U. S. Geol. Surv., p. 182, 1897.

IV. Shonkinite, Yogo Peak, Little Belt Mountains, Montana. Hillebrand, analyst. WEED and PIRSSON, *Am. Jour. Sci.*, Vol. L, p. 474, 1895.

V. Essexite, Salem Neck, Mass. Washington, analyst. JOUR. GEOL., Vol. VII, p. 57, 1899.

The mineralogical composition of these rocks is such that their calculation must, of necessity, be arbitrary and only approximate, but those of I, II, IV, and V may be very roughly reckoned out, as below, that of IVa being Pirsson's calculation.

	Ia	IIa	IVa	Va
Orthoclase	29.3	29	25	16.3
Albite	22.8	..	10	13.3
Anorthite	....	..		17.2
Nephelite	9.0	23	..	20.1
Haüyne	....	4	..	....
Aegirite	4.5	4	..	3.7
Diopside	9.0	25	35	3.7
Hornblende	18.8	..	5	7.2
Biotite	....	..	18	....
Olivine	....	2	7	9.2
Magnetite	2.5	7	..	4.3
Titanite	3.1	2	..	4.0
Apatite	1.0	4	..	1.0
	100.0	100	100	100.0

In my former paper I discussed briefly the position of this rock in classification, and provisionally put it with the shonkinites. At that time the mineralogical composition had not been calculated, and this position was assigned to it because it resembled Pirsson's shonkinites, except in the presence of nephelite and of hornblende instead of biotite, and also because it came under Rosenbusch's definition[1] of these rocks, whose essential features according to him, are the presence of abundant dark minerals along with nephelite and orthoclase. As was also remarked, it cannot be put with the essexites or theralites (although chemically closely resembling these), on account of the lack of plagioclase.

In this connection it is of great interest to note the fact that, in his latest description[2] of typical theralite, J. E. Wolff states that there is nothing which can strictly be called soda-lime feldspar present. Indeed this fact is evident from a consideration of the analyses by Hillebrand, published in the same place. The name theralite, therefore, cannot be applicable to Wolff's Montana rocks, or else its definition must be changed.

---

[1] ROSENBUSCH, *Elemente der Gesteinslehre*, p. 174, 1898.

[2] *Bull. U. S. Geol. Surv.*, No. 150, p. 197, 1898.

It will be seen that, though the covite and the theralite of Wolff resemble each other in qualitative mineralogical composition, as both are composed essentially of alkali-feldspar, nephelite and ferromagnesian minerals, and that both are distinctly leucocratic in character, yet that in a quantitative mineralogical way they are decidedly different. The feldspathic constituents of the covite are very largely feldspar, with only accessory amounts of nephelite, while the theralite shows about as much feldspathoid as feldspar. The calculation of the latter cannot be exact, since some of the soda goes into the feldspar, but this must be small, and cannot affect the result to any great extent. It is evident, then, that the name of theralite is not appropriate for the Magnet Cove rock, though it might be used in the present very vague and loose method of classification, based largely on qualitative mineralogical composition.

A comparison of Pirsson's descriptions[1] with Rosenbusch's definition of shonkinite indicates that the latter has been apparently laboring under a misapprehension of the former's descriptions, and that his definition does not cover the rocks as Pirsson described them. Pirsson expressly states in each case that nephelite is either entirely absent or present only in mere traces, which does not coincide with the definition which makes nephelite an essential constituent.

Although resembling each other in many ways, yet there are certain striking differences between the analysis of the Magnet Cove rock and those of shonkinite. In SiO_2, iron oxides, CaO and K_2O they are closely alike, but in the Magnet Cove rock Al_2O_3 and Na_2O are higher and MgO lower. Indeed the calculations of the mineralogical composition, though that of Ia is only approximate, show clearly that while the "covite" is distinctly leucocratic the shonkinite is as decidedly melanocratic. A similar distinction will be pointed out between the "leucite-porphyry" and missourite. In this respect the rock under consideration resembles the typical essexite, though here again there is a distinct difference in the amount of K_2O, in the essexite this being much lower, and plagioclase entering to a very considerable extent.

---

[1] L. V. Pirsson, *Bull. Geol. Soc. Am.*, Vol. VI, p. 408, 1895; *Am. Jour. Sci.*, Vol. L, p. 474, 1805; *Am. Jour. Sci.*, Vol. I, p. 358, 1896.

For this leucocratic holocrystalline combination of orthoclase (alkali-feldspar) and less nephelite, with hornblende and aegirite-augite, of granitic structure, and with a composition like that given in the analysis above, I would propose the name of Covite. If only the qualitative, not the quantitative, mineralogical composition be considered, the covites may be called basic nephelite-syenites or foyaites. But the whole tendency of modern petrography is, rightly, against this narrow view of rock classification, and the use of a new name seems to be abundantly justified. In ordinary typical foyaites the alkali-feldspars and nephelite, etc., make up from 75 to 90 per cent. of the rock, the dark minerals consequently only from 10 to 25 per cent. In the covites, on the other hand, while the type is rather leucocratic, the light and dark minerals are present more nearly in the same amount, and these rocks might justly be called "mesocratic."

As a matter of fact, accepting Pirsson's definition of shonkinite as the standard (viz., melanocratic combination of alkali-feldspar with pyroxene, etc.), the covites are the rocks which correspond to Rosenbusch's definition of shonkinite. A similar rock, which also belongs here, is that the analysis of which is given in III, and which Cross provisionally called a "tinguaite."

Arkite ("*Leucite-porphyry*").—The specimen which was selected for analysis came from an exposure a little to the northeast of and above Diamond Jo quarry. Judging from the other specimens which I collected around the area, it seemed to be representative and an average specimen of the occurrences. A good sized hand specimen was used for the analysis, so as to obtain a fair sample of this rather coarsely porphyritic rock.

The results, given in I, were rather surprising in comparison with the analysis by W. A. Noyes of another specimen from the neighborhood (II). Not only is SiO_2 much lower, but MgO is a little higher, CaO much more so, and, though the total amount of alkalis remains the same, the new analysis shows a rock relatively richer in potash as compared with soda.

	I	II	III		I	II	III
SiO_2	44.40	50.96	46.06	ZrO_2	0.03	....	....
Al_2O_3	19.95	19.67	10.01	P_2O_5	0.37	....	0.21
Fe_2O_3	5.15	7.76	3.17	SO_3	0.06	trace	0.05
FeO	2.77	.....	5.61	Cl	trace	0.25	0.03
MgO............	1.75	0.36	14.74	MnO............	0.08	trace	trace
CaO	8.49	4.38	10.55	BaO	0.01	....	0.32
Na_2O	6.50	7.96	1.31	SrO.............	....	....	0.20
K_2O	8.14	6.77	5.14				
H_2O (110°+)....	1.17	1.38	1.44		100.76	100.01	99.57
H_2O (110°−)....	0.24	.....	.....	Less O = Cl	......	0.06	0.01
CO_2	0.12	.....	.....				
TiO_2............	1.53	0.52	0.73		......	99.95	99.56

I. Arkite, Magnet Cove. Washington, analyst. Sp. gr., 2.770 at 26° C.

II. Arkite, Magnet Cove. Noyes, analyst. WILLIAMS, *op. cit.*, p. 276.

III. Missourite, head of Shonkin Creek, Highwood Mountains, Montana. Hurlbut, analyst. WEED and PIRSSON, *Am. Jour. Sci.*, Vol. II, p. 321, 1896.

The discrepancy between the two analyses of the leucite rock cannot be explained by the supposition that the specimen analyzed by Noyes carried a larger proportion of pseudo-leucite, since, although the other constituents work out well on this basis, the amount of K_2O in II is not intermediate between that in I and in Williams' analysis of a pseudo-leucite crystal. It seems to be the case that Noyes' specimen represents a slightly different phase, possibly richer in aegirite, but poorer in diopside and garnet. From my own observations in the field and the specimens collected, I conclude that the specimen of I represents the normal rock more closely than that of II.

It may be remarked that this supposition is borne out by the fact that analysis I is, in a general way, intermediate between that of the covite and that of the ijolite, given later, while Noyes' is not. This is to be expected in view of the observation noted in my former paper (p. 395), that "while the relations of the 'fine grained' (shonkinitic) syenite to the leucite-porphyry are uncertain, the former lies apparently outside or above the latter."

In the absence of discrimination between the two iron oxides in II, it is impossible to make a satisfactory calculation of Noyes' analysis, but No. I works out thus, the result being only an approximation, owing to the composition of the rock. In IIIa is given that of the missourite, as calculated by Pirsson.

	Ia		IIIa
Orthoclase	3.9	Leucite	16
Leucite	36.9	Analcite	4
Nephelite	25.5	Zeolites	4
Aegirite	8.4	Augite	50
Diopside	10.8	Olivine	15
Garnet	14.5	Biotite	6
		Iron ore	5
	100.0		100

It is evident from this table that while both rocks are alike in being composed essentially of leucite, with subordinate nephelite (or zeolites), and dark minerals, yet that they differ radically from each other, just as did the covite and shonkinite. The Magnet Cove rock is distinctly leucocratic, carrying about 66 per cent. of light minerals, while the missourite is as decidedly melanocratic, carrying only 24 per cent. of these.

It is obvious from the mineralogical composition, as well as from the analysis, that the name "syenite" which has been applied to this rock is not justified, if this term is to retain any precision of meaning except that of indicating the absence of quartz and an alkaline character. Since this is so, and since the rock represents a most interesting and quite distinct type, it certainly should have a distinct appellation of its own.

It would seem peculiarly appropriate to honor the memory of its first describer, J. F. Williams, by calling it Williamsite. But since this name has been already preëmpted by Shepard for a variety of serpentine, and as it would be a solitary exception among rock names, it will be best not to do so. I propose, therefore, the name of "arkite" (from the usual abbreviation of the state name Arkansas), the essential features being a holocrystalline, porphyritic, leucocratic combination of leucite (or pseudo-leucite) and nephelite, with pyroxene and garnet.

Ijolite.—The analysis of this type, from below Dr. Thornton's, has been already published,[1] but is here repeated, with the addition of several constituents which have been determined since. In II is given the analysis of a typical ijolite from Iiwaara, in Finland. The two do not differ materially, except that I is higher in CaO and correspondingly lower in Na_2O.

	I	II		I	II
SiO_2	41.75	43.70	CO_2........	none	....
Al_2O_3	17.04	19.77	TiO_2	0.58	0.89
Fe_2O_3	6.35	3.35	ZrO_2	0.05	....
FeO	3.41	3.94	P_2O_5	1.09	1.34
MgO........	4.71	3.94	S	none	....
CaO	14.57	10.30	MnO	trace	trace
Na_2O	6.17	9.78	BaO	none	....
K_2O........	3.98	2.87			
$H_2O(110°+)$	0.62	0.89		100.60	100.30
$H_2O(110°-)$	0.28				

I. Ijolite, Magnet Cove. Washington, analyst. *Bull. Geol. Soc. Am.*, Vol. XI, p. 399, 1900. Sp. Gr. 3084—26°C.

II. Ijolite, Iiwaara, Finland. Sahlbom, analyst. V. HACKMAN, *Bull. Com. Geol. Finl.*, No. 11, p. 17, 1900.

The mineralogical composition of the two is given below, that of IIa being Hackman's calculation. II is almost exactly half nephelite, while I contains rather less than half of this mineral, but both may reasonably be called mesocratic. Hackman's specimen did not contain any garnet, but this is a very

	Ia	IIa[2]
Nephelite..........	38.7	55.00
Aegirite...........	4.6	7.15
Diopside	31.3	33.22
Augite	6.9	.....
Melanite	15.3	.....
Titanite...........	....	2.16
Apatite	3.0	3.17
	100.0	100.70

---

[1] H. S. WASHINGTON, *op. cit.*, p. 399.

[2] There is a clerical error in Hackman's results, as he gives the nephelite as 51.02, the sum as 100.50.

variable constituent in the Finland ijolites. Hackman (*op. cit.*, p. 4) notes the identity between the Magnet Cove rock and the Finland and Alnö ijolites.

Biotite-ijolite.—An analysis was also made of this rock, the specimen coming from near the Baptist church, and the results are given in I. My specimen was, unfortunately far from fresh, so that the figures are of little value. Williams' analysis (II) of the same type, undoubtedly made on fresher material, is to be preferred. The chief feature of interest in I is the (for this oxide) large amount of ZrO_2, which may be correlated with the neighboring "eudialyte-syenite pegmatite" described by Williams.

	I	II		I	II
SiO_2	38.11	38.93	SO_3	none	....
Al_2O_3	20.84	15.41	Cl	....	0.02
Fe_2O_3	5.67	5.10	S	0.14	0.89[1]
FeO	1.46	4.24	MnO	0.14	trace
MgO	3.80	5.57	BaO	trace	....
CaO	14.44	16.49	SrO	....	trace
Na_2O	6.65	5.27	Li_2O.......	....	trace
K_2O	2.12	1.78			
H_2O(110°+)	4.51	5.20		100.60	100.87[2]
H_2O(110°−)	0.57		Less O	0.04	
CO_2	0.65	....			
TiO_2	0.48	1.62		100.56	
ZrO_2	0.18	....	Sp. Gr.	2.679—26° C.	
P_2O_5	0.84	0.35			

The composition of the rock is such that any calculation of the mineralogical composition must be rather arbitrary and unsatisfactory, but the following (IIa) represents roughly and

	IIa.
Orthoclase - - - -	4.8
Nephelite - - -	24.1
Biotite - - - - -	6.2
Diopside - - -	30.6
Melanite - - - - -	23.0
Schorlomite - - -	6.7
Magnetite - - - - -	3.6
Apatite - - - -	1.0
	100.0

---

[1] FeS_2.

[2] Williams gives 100.57.

approximately that of Williams' specimen. It is probable that my specimen was rather richer in nephelite and poorer in dark minerals than Williams'. The composition is much the same in a general way as that of the ijolite, only that it is melanocratic, rather than mesocratic.

Jacupirangite.—A new analysis was made of the dark, coarse-grained rock, composed largely of augite, which occurs as a small mass northeast of the main area, on Cove Creek. This was deemed to be advisable since the analysis of Williams showed more CaO, or less MgO and FeO, than was necessary to form augite or any other mineral present. The analysis of Williams is given in I, and my results in II, with two other analyses for comparison.

No.	I	II	III	IV
SiO_2	36.51	38.39	38.38	45.05
Al_2O_3	8.22	7.05	6.15	6.50
Fe_2O_3	8.29	9.07	11.70	3.83
FeO	3.31	6.17	8.14	7.69
MgO	8.19	11.58	11.47	12.07
CaO	18.85	19.01	18.60	18.82
Na_2O	2.10	0.74	0.78	0.94
K_2O	1.08	0.75	0.13	0.78
H_2O 110°+	1.40	0.33	0.54	2.40
H_2O 110°−	....	0.14	0.18	
CO_2	....	0.32	none	....
TiO_2	3.11	4.54	4.32	2.65
ZrO_2	....	none	....	....
X	....	0.24	....	....
P_2O_5	....	0.82	0.17	0.15
Cl	0.03[1]	....	....	....
S	6.03	0.42	....	....
MnO	trace	0.32	0.16	....
BaO	....	trace	....	....
SrO	trace	....	....	....
	99.22	99.89	100.72	100.88

Sp. gr., 3.407—26° C.

I. Jacupirangite, Magnet Cove. J. F. Williams, analyst. *Op. cit.*, p. 227.

II. Jacupirangite, Magnet Cove. H. S. Washington, analyst.

III. Jacupirangite, Jacupiranga, Sao Paolo, Brazil. H. S. Washington, analyst.

IV. Pyroxenite, Brandberget, Gran, Norway. L. Schmelck, analyst. W. C. BRÖGGER *Q. J. G. S.*, Vol. L, p. 31, 1894.

[1] FeS_2.

While I and II are alike in a general way, yet there are marked differences in SiO_2, FeO, MgO and S. The specimen analyzed by Williams carries considerable pyrite, while mine only showed a few specks of it. The differences in the other constituents named may be attributed to alteration, especially in view of Williams' statement that the specimen analyzed by him was not fresh.[1] Analysis II calculates out readily as follows:

	IIa
Nephelite	4
Diopside	64
Augite	15
Biotite	5
Magnetite	8.7
Pyrite	0.7
Calcite	0.6
	100.0

In my former paper this pyroxenite was referred somewhat doubtfully to the jacupirangite of Derby. Through the kindness of this gentleman, to whom I would express here my deep acknowledgments, I have lately received numerous specimens of the Brazilian types. A comparison of these with the Magnet Cove specimens makes it evident that the two occurrences differ chiefly in size of grain, the Arkansas rock being very coarse, while those from Brazil are much finer grained. In all other essential respects the two are closely alike.

From the microscopical examination of the specimens which Professor Derby sent me, it is evident that the "Jacupirangites" of Brazil vary from rocks rich in nephelite, and which are true ijolites, closely analogous to those of Magnet Cove and Finland, through rocks composed predominantly of pyroxene, with small and varying amounts of magnetite and nephelite, to types extremely rich in magnetite and with no nephelite or only traces of this mineral. Accepting then the name of Jacupirangite for the medium type, the application of this name to the Magnet Cove rock is abundantly justified, since the only difference is the comparatively unimportant one of size of grain, both being holocrystalline.

---

[1] WILLIAMS, *op. cit.*, p. 227.

That this identity of the two, based on mineralogical grounds, is correct, is substantiated by a chemical analysis of one of Derby's specimens made by myself. For this purpose an apparently medium specimen was chosen, composed largely of a violet-brown augite, with some magnetite (more than in the Arkansas rock) and only a little nephelite (less than in the other). No biotite was present, and only traces of apatite. This analysis, given in III of the table, is most remarkably close to that of the Magnet Cove jacupirangite in all respects, except the iron oxides. Indeed the figures for silica, magnesia, lime, soda, water, titanic acid and manganese are close enough to belong to duplicate analyses of the same specimen, and those for alumina and potash do not differ greatly. The higher iron oxides are of course connected with the more abundant magnetite, but, apart from this, the mineralogical composition is closely similar.

The closest known analogue of these rocks is probably the pyroxenite of Brandberget, an analysis of which is given in IV above. The only noteworthy differences are in SiO_2 and Fe_2O_3. That of the former apparently conditioned the formation of nephelite in the Magnet Cove and Brazil rocks and plagioclase at Brandberget, while the higher ferric oxide of II and III is to be connected partly with the more abundant magnetite in the former.

HENRY S. WASHINGTON.

[*To be continued.*]

THE PRE-TERRESTRIAL HISTORY OF METEORITES.

THE completion of the studies for students relating to the composition and structure of meteorites, which have recently been published in this JOURNAL, furnishes an opportunity for me to record certain deductions which seem to me warranted by the facts there presented, but which, being largely theoretical, had best be stated as the expression of individual opinion.

That theories of the origin and cosmic history of meteorites have been propounded before, and that these have varied widely in character, the present writer is well aware. These theories may be mentioned at the outset, together with the names of those who have given them special support, without, however, entering into any discussion of the merits of each.

Meteorites have been declared to be (1) terrestrial matter discharged into space by the volcanoes of the earth and returned to it again (Sir Robert Ball); (2) matter discharged from the volcanoes of the moon (La Place, J. Lawrence Smith); (3) matter ejected from the sun (Sorby); (4) portions of shattered stars (Meunier); (5) portions of a shattered planet (Boisse); (6) portions of comets (Newton); (7) clouds of gas or dust cemented and solidified by the action of the earth's atmosphere (Brezina).

All of these hypotheses have been urged by men of eminence, each urging strong reasons for his views. These reasons can be learned by study of the original authorities, and the discussion of them in the present article is not a part of my purpose. I shall endeavor here simply to present my own views and my reasons for the same.

The study of meteorites has shown that:

1. The majority of iron meteorites are octahedral.
2. The majority of stone meteorites are chondritic, and contain considerable glass.
3. Between iron and stone meteorites there is every gradation—they are formed of the same sort of matter.

The above statements would probably not be questioned by any authorities of the present day. The following, however, might not be agreed to by all:

4. The substance of meteorites was in a solid state before the fall of these bodies to the earth.

5. The structure of the majority of meteorites shows that their substance has cooled from a liquid or semi-liquid condition to that of a solid.

6. The structure of the majority of iron meteorites shows that the change from a liquid or semi-liquid to a solid state has taken place slowly.

7. The structure of the majority of stone meteorites shows that the change from a liquid or semi-liquid to the solid state has taken place rapidly.

The four latter statements may then be briefly discussed, and important known objections to them stated.

Concerning statement 4: It was suggested by writers in the early part of the last century that meteorites were concretions formed in our own atmosphere. Brezina inclines to accept this view with the modification that the substance of meteorites was extra-terrestrial, but that it arrived at the earth in the shape of gas or dust and was cemented or solidified by the earth's atmosphere. To my own mind, the slickensided surfaces and veins exhibited by many meteorites afford sufficient contradiction of such a view, and compel the conclusion that the matter in which such structures occur had existed in a solid state for a considerable length of time before it reached the earth.

Concerning statement 5: Several writers, but especially Daubree,[1] have expressed the conviction that the substance of meteorites gives evidence of having passed directly from a gaseous or vaporous state to that of a solid. The opinion seems to be based chiefly on Meunier's synthetic experiments, in which he succeeded in reproducing mineral aggregations having the composition of meteorites and somewhat resembling them in structure, by the inter-action of vapors.[2] But, as pointed out by Cohen,[3] the absence of gas and vapor pores in meteorites

[1] "Observations sur les conditions qui paraissent avoir preside a la formation des meteorites," *Comptes Rendus*, 1893, CXVI, pp. 345–7.

[2] *Encyclopedie Chimique*, Tome II, "Meteorites," chap. v.

[3] *Meteoriten-kunde*, Heft I, p. 327.

argues against such an origin of their substance, and further, Fouqué and Lévy produced by cooling from fusion, mineral aggregates as closely resembling meteorites as those made by Meunier from vapors. Again, the crystalline structure of the minerals of meteorites perfectly resembles that of terrestrial minerals known to be produced by cooling from fusion.

Concerning statement 6: That the complete crystalline structure possessed by the great majority of iron meteorites indicates a lapse of time sufficient for a slow, uniform arrangement of the molecules of their mass, in other words a slow cooling, has rarely been doubted. Such a conclusion certainly accords with all terrestrial experience and observation. It has been suggested by Cohen,[1] however, that the crystalline structure expressed in iron meteorites by the Widmanstätten figures may be really a sort of skeleton growth, similar to that seen when needles of ice form over the surface of rapidly cooling water, and that hence the Widmanstätten figures may indicate a rapid crystallization. It is unfortunate that no attempt to reproduce Widmanstätten figures artificially in iron has ever yet succeeded, for if this could be done valuable evidence for judgment on this point could be secured.

Taking the evidence as it stands, however, and especially taking into consideration iron meteorites like that of La Caille, whose structural features show a complete parallelism throughout a large entire mass, the indications seem to me to point strongly to slow crystallization. Certainly analogies between the formation of crystals in iron and in water should be drawn with hesitation. Iron is far more viscous than water and movement in it would take place slowly. Further, the crystalline plates of meteoritic iron differ in composition, showing that time must have elapsed for separation of ingredients as has not taken place in the ice formed upon water.

Concerning statement 7: This opinion is based chiefly on the large quantity of glass found in most of the chondritic meteorites, which, it is to be noted, make up by far the larger quantity of known stony meteoritic matter. Glass is known to indicate rapid cooling. Further, the character of the chondri themselves is such as to lead many students of the subject, notably Brezina and Wadsworth, to believe that they are the result of rapid and arrested crystallization. The fact that chrysolite, the least fusible and therefore the earliest cooling mineral, forms the most chondri, lends support to this view. It must be confessed that the real origin of chondri is as yet very obscure and the theory above suggested is far from accounting for many of their peculiarities. Yet the facts above noted seem to me to argue more strongly in favor of a rapid cooling of the substance found in such meteorites than a slow one.

---

[1] *Meteoriten-kunde*, Heft I, p. 326.

If the arguments in favor of the above statements seem sustained, then the conclusion to which they appear to me to point is the following: *Meteorites are portions of a disrupted mass of cosmic matter which had a spheroidal form, increased in density toward the center, and cooled from a liquid or semi-liquid to a solid state before disruption.*

The application of this hypothesis to the subject in hand may perhaps best be traced by applying it in a reverse order. Given a defined quantity of liquid or semi-liquid. It will take the form of a spheroid, since this is the only form known in which a liquid mass would maintain itself in space. Its materials would arrange themselves according to density. The iron, for example, would sink to the center, and the slag-like silicates rise to the surface, as they may daily be seen to do in a blast furnace, or as a centrifugal separator assorts substances according to density. The exterior of the sphere owing to contact with the cold of space would be cooled with comparative suddenness, giving the minerals of the surface a glassy, brittle character. The protected interior would cool more slowly, giving the molecules of the metallic center an opportunity to arrange themselves in an orderly, crystalline fashion. In time, however, the globe becomes solidified from center to circumference. During the process of solidification, and later, many processes of disruption and adjustment go on as the result of strains of various kinds, record of which is to be found in the structure of meteorites. Fissures will be formed, into some of which pasty metallic matter will be forced from below, and which will, in its passage upward, enclose angular fragments of the siliceous crust. Other fissures occurring only in the siliceous portion of the globe will give rise to the formation of quantities of angular fragments, which will be cemented together again by pressure to form breccias. Such fissures would be comparatively large, and affect a considerable area of the globe. Other minor fissures would form in ramifying networks, which would be filled by adjacent substance penetrating in a more or less liquid form. Differential movements of solid portions, without the existence of fissures, would produce slickensided surfaces. Finally, the progressive disruption of the body occurs. To produce this, two or three forces may be appealed to. In the first place, there is the familiar fissuring from shrinking and contraction as the body passes from the liquid to the solid state. It is perfectly evident that a certain amount of this is taking place upon the earth.[1] Meunier suggests further, that in the moon we can see this process extended as much farther as the moon is more fully cooled than the earth, and he regards the well-known bright streaks of the moon as enormous fissures (*rainures*) showing a progressive disruption of its mass.[2] While few probably at the present day would accept this interpretation of the bright streaks of the moon, there are numerous other indications that the moon is considerably fissured. Meunier also points to the asteroids as an illustration of a dismembered heavenly body.

In the second place, strains corresponding to the tidal strains of the earth would produce a constant disruptive effect; and, in the third place, the recent investigation of Professor Chamberlin,[3] has shown how the fragmentation of a small body may take place by near approach to a large one.

Once the body is broken up, its fragments may be drawn out into the form of a somewhat attenuated swarm or cluster. The possibility of the subsequent capture of single portions of such a cluster by the earth can hardly be denied. The character of the portion captured, in respect to its structure, density, and composition, then, will depend on the position it occupied in the globe of which it formed a part.

---

[1] See CHAMBERLIN, "On a Possible Function," etc., JOUR. GEOL., Vol. IX, No. 5.

[2] *Cours de Géologie Comparée*, pp. 258 *et seq.* [3] *Op. cit.*

That meteorites exist in such swarms in space seems very probable from a recent investigation of Högbom.[1] Plotting the known meteorite falls according to the days of the year, he has discovered undoubted and significant groupings. Thus of the nine known howardites, three fell during the first days of August, and three during the first half of December. The probabilities are stated to be several thousand to one against such an occurrence being a mere coincidence. Again, of the three known eukrites two fell June 13–15. The chances are said to be ninety to one that these had a common origin. There are numerous other groups brought out on the chart so made, which seem to point to the existence in space of meteorite clusters met on the same date by the earth in its annual revolution. The probabilities seem sufficiently in favor of the existence of such clusters to warrant placing some reliance in the constitution indicated for them. Thus with the group of August howardites previously mentioned are associated one siderite and three chondrites; with the December howardites, one siderite, one bustite, one chladnite, and a number of chondrites. The constitution indicated for these swarms resembles therefore, to a remarkable degree, that called for by the hypothesis here advocated, especially when it is remembered how exceedingly fragmentary must be evidence based on the few meteorites seen to fall. A similar constitution has been also exhibited at times in the substance of a single meteoric shower. A notable case is that of Estherville, which contained all gradations, from iron to stone meteorites.

Two or three other points of evidence may be noted as tending to show that, in such a globe as that assumed, the substances were arranged in order of their densities and that it had at some time a hot interior and cold exterior.

---

[1] *Bull. Geol. Inst. of the University of Upsala*, Vol. V., Part I.

The first is drawn from our knowledge of the crystallography of iron. According to modern metallographists, iron occurs in three allotropic modifications known as alpha, beta, and gamma irons. When heated to a temperature not higher than 700° C., iron remains in what is known as the alpha state; from 700 to 860° C. it assumes the beta state, and from 860° C. to the melting point, the gamma state. In cooling, from the melting point, for instance, the iron does not necessarily return through these modifications, but remains in the state which it assumed at the highest temperature.[1] Now gamma iron crystallizes in octahedrons, while alpha and beta iron crystallize in cubes. The majority of meteoritic iron is plainly octahedral in structure. It is hard to escape the conclusion, therefore, that it has been heated to a temperature at least as high as 860° C., and, further, that the cubic irons, some of which occur among meteorites, have been subjected to a somewhat lower degree of heat. The latter, it is true, must be cooled and reheated to a somewhat lower temperature than at first to have their structure accounted for on this theory. But this could quite reasonably occur, and their relative quantity is so small as to make them of minor importance.

A second corroborative fact is that the carbonaceous meteorites are of exceptionally low specific gravity. Now the carbonaceous meteorites are those which contain hydrocarbons which could not exist under any high degree of heat. Such meteorites could not have experienced any sensible heating subsequent at least to the formation of these hydrocarbons. But the low density of these meteorites would place them, according to the hypothesis, on the outer surface of the spheroid, where, after the first solidification from cooling, little further heating would be encountered.

A third corroborative fact is found in the existence of diamonds in the iron meteorite of Cañon Diablo, a meteorite which exists in quantity amounting to several tons. Such diamonds have been produced by Moissan by heating to a high temperature iron saturated with carbon and allowing it to cool under pressure. This is exactly the process through which the substance of an iron meteorite would pass if formed according to the above hypothesis. The other meteorite known to contain diamonds, Nowo-Urej, is also one which would have formed not far from the metallic center of such a globe, as it contains large metallic veins and by some is classed among the iron-stone meteorites.

---

[1] F. OSMOND, *The Metallographist*, July, 1900.

The hypothesis outlined above may ask the special attention of the geologist, on account of the suggestions it may offer regarding the history of the earth. If it be true that meteorites are fragments of a broken-up globe, it is not unlikely that they show to us, to some extent, the constitution of our own globe. Uniformity of cosmic matter has been indicated by all studies of meteorites, as well as by all spectroscopic inquiries into the chemistry of space. Uniformity of cosmic history seems therefore probable also.

I have shown in the studies previously referred to that meteorites chiefly differ in composition from the crustal terrestrial rocks with which we are familiar in having an excess of iron, nickel, and magnesium, and in being practically without free silica, oxygen, and water. Assuming that the earth, however, has passed through a history like that of the globe above hypothesized, the absence of iron, nickel, and magnesium[1] from its crust is explained by the conclusion that they have been carried within its interior by their density. They are therefore removed from our observation, except as occasional outflows such as that known in Greenland bring them to view. It is well known that the density of the earth as a whole requires that its interior contain matter of higher specific gravity than that with which we are familiar upon its crust, and it has often been suggested that this matter may be iron and other metals. The alternative supposition is that the matter of the interior may be like that of the crust but has become denser through condensation and pressure.

---

[1] Magnesium is here referred to not as the element, which is relatively light, but as the essential constituent of chrysolite, which is of high specific gravity and forms some of the heaviest terrestrial eruptive rocks.

The free silica of the earth's crust is readily accounted for if we remember that the rocks of the earth's crust have been *worked over*, while in meteorites they are seen in their primitive condition. When silicates are exposed to the action of carbonic acid for any length of time the bases change to carbonates and silica is set free.[1] It seems reasonable to suppose that the vast amount of calcium and magnesium now held as limestone was originally in the form of silicates. If the carbonic acid of the limestones should be withdrawn to the atmosphere, and their bases combine with the excess of silica of the crust, rocks as basic as those of meteorites would probably be formed.

Similarly, the lack of oxygen in meteorites may be only relative, and because much of the matter of which they are composed was in the interior, deep-seated and protected from gaseous action. The superficial, lighter siliceous portions of meteorites are found to be oxidized. It is reasonable to believe the earth's substance is not oxidized except for its superficial crust. It may be urged in support of the view that oxygen could not have been present where meteorites were formed that little or no oxygen is found among the free gases obtained from meteorites. But rocks do not seem to have the power of absorbing and holding oxygen as they do other gases. Terrestrial rocks do not contain it, although they hold hydrogen, carbon dioxide, and carbon monoxide in large quantities.[2] Yet there is no lack of oxygen in the earth's atmosphere.

The absence of water from meteorites is an important gap in the parallelism of constitution of meteorites with that of the earth. In the gases hydrogen and oxygen, which it has been shown meteorites possess, a cosmic body has the elements necessary for the formation of water. Conditions of nascence, or possibly of electricity, might exist in a body the size of the earth, which would lead to the formation of water from these gases, which might not prevail upon a body of smaller size. The chief reason, however, for the absence of water from meteorites seems to be the fact that the size of the meteorite spheroid was probably not sufficient to enable it to hold a quantity of the free gases competent to the formation of water or even to retain water vapor if it was once formed. The spheroid was probably as destitute of an atmosphere as the moon.

---

[1] This fact is more fully stated by SIR JOHN MURRAY, *Proc. Roy. Soc. of Edinburgh, 1890–1*, p. 229.

[2] See *Studies*, JOUR. GEOL., Vol. IX, p. 402.

I am well aware that an origin of meteorites from a shattered globe has been suggested before. Boisse was perhaps the first to do this,[1] but the idea was especially elaborated by Meunier,[2] who reconstructed from the various types of meteorites a hypothetical globe in which these types were arranged largely in accordance with their density. But the hypotheses of these authors were based purely on considerations of density, it being arbitrarily assumed that in a cosmic body substances *would* arrange themselves according to density.

It was when a study of the structural characters of meteorites showed me that the substances *had* apparently arranged themselves in the order of their density, and exhibited corresponding differences of structure, that I was led to form the above hypothesis; and it is perhaps worth remarking that I reached this conclusion before I had seen Meunier's papers on the subject.

It is not likely that the globes or spheroids, such as have been here hypothesized, were of large size. In the solar system, for example, there is no indication that the total disruption of a body anything like in size to a planet has ever taken place. Such an occurrence would produce effects more catastrophic in their nature than could be referred to matter so small in relative quantity as that which has within human experience reached the earth in the form of meteorites. Such globes would, perhaps, in their entirety, never come within human observation. But that there exists in space a vast quantity of fragmental matter beside that visible to us as stars, nebulæ, and the bodies of the solar system, there can be little doubt.

OLIVER C. FARRINGTON.

---

[1] *Memoires de la Société des lettres, sciences et arts de l'Aveyron*, Vol. VII, p. 168.

[2] *Cours de Géologie Comparée.*

EDITORIAL

WITH this number we present to the readers of the JOURNAL two able articles on geologic classification and nomenclature. It is expected that these will be followed by others representing different points of view. In the opening numbers of the next volume we hope to offer a series of very carefully matured articles on the classification and nomenclature of minerals and rocks, by some of our foremost petrographers. It is hoped that these discussions will receive the thoughtful consideration of progressive geologists and petrographers. The importance of revising our present systems of classification and nomenclature, if systems they may be called, is equaled only by the importance of thorough preliminary scrutiny of the proposed substitutes, lest we impose on ourselves new systems scarcely less infelicitous than the old. A critical and deliberate circumspection, attended by full discussion, may well be followed by the adoption of the improved systems by those who have become convinced of their merits, if full liberty to follow the old practice is unreservedly accorded to the unconvinced and to the constitutionally conservative. It is doubtful whether we should try to force new systems into usage by legislative processes, but concerted adoption by those who have the courage of their convictions will go far towards securing the desired end.

T. C. C.

REVIEWS.

Zinc and Lead Region of North Arkansas. By JOHN C. BRANNER (Arkansas Geological Survey, Annual Report 1892, 396 pp., Little Rock, 1901.)

THE lead and zinc deposits of the Ozark region have received attention from the geological surveys of Arkansas, Missouri, Kansas, and the federal government. The United States Geological Survey and the University Geological Survey of Kansas will shortly have out reports on the subject. Missouri, through her geological survey, has already published an exhaustive account of the deposits in two large volumes, by Mr. Arthur Winslow. After delays of nearly ten years, Arkansas has at last seen fit to make appropriations for the publication of the report on the zinc and lead deposits of the north part of the state. It is by the former state geologist, Dr. J. C. Branner.

The publication of Dr. Branner's report has long been looked forward to by all interested in the subject of lead and zinc. In many respects it is the most welcome contribution to our knowledge of the geology of the Ozark region that has yet been made.

Preliminary to the consideration of the ores is a short description of the surface relief of the region, illustrated by an excellent photographic reproduction of Branner's Relief Model of Arkansas. The zinc and lead deposits described are located chiefly north of the Arkansas river. "The region here included under the name of Ozark plateau embraces nearly all of that part of the Ozark mountains within the state of Arkansas. It includes almost the entire region between the Arkansas river and the Missouri line, and between the St. Louis, Iron Mountain & Southern railway and the Indian Territory line. The Ozark region in Arkansas is made up of three plateaus that rise like ragged-edged steps one above another, each with a few outliers standing out upon the next step below."

In order of their importance, the zinc ores of northern Arkansas are sphalerite, smithsonite and calamine, besides several other minerals of zinc which do not occur in sufficient quantities to entitle them to be looked upon as ores.

The zinc ores are regarded as having been deposited by underground waters. Emphasis is laid on their accumulation along synclinal troughs and water-way breccias. "The details of the theory of the accumulation of the Arkansas ores along synclines and other water-ways were first suggested by field observations made in this region in 1889, and the whole theory has been much strengthened by subsequent work."

According to their genetic relations there are three kinds of sulphide ores: (*a*) the bedded deposits, which are contemporaneous with the rocks in which they occur; (*b*) the veins and other fracture deposits in which the ores are of later age than the accompanying beds, and (*c*) the breccia deposits not formed on fractures, but likewise of later age than the accompanying beds. In addition to the sulphide ores there are carbonate and silicate ores, derived by alteration from the sulphides and forming genetically a fourth class.

Regarding the origin of the bedded deposits, it is stated that they "have originated for the most part where we now find them." The cherts are made of silica of organic origin, that is, they were deposited over the sea bottom as silicious skeletons of diatoms or other microscopic remains of plants or animals. The zinc came from the adjacent land areas of the period in which these beds were laid down. Upon entering the sea the zinc-bearing waters had their zinc contents precipitated in the form of sphalerite or zinc sulphide by the organic matter that contributed the silica of the chert beds. The zinc crystallized out while these silicious sediments were yet soft and yielding. In time the sediments hardened and formed the firm, flinty rocks and pressed closely about the zinc blende crystals.

"The crystals of zinc blende, however, were not originally as large as we now find them in the disseminated ores, even where these crystals are no larger than a pin head. They were at first even microscopic, but, as Ostwald has pointed out, there is a tendency in such cases for the small crystals to pass into solution and to recrystallize upon the larger ones which grew at the expense of the small ones. In the bedded deposits this took place before the enclosing sediments were hardened."

The vein deposits are those occupying the spaces left by fractures in the strata. The ores are confined to the fractured zone and to its immediate walls. When the ore is found in the walls it seldom penetrates them to any considerable depth, but is confined to small fractures that seem to be parts of the great fissures. In appearance the fissure ores are not different from the bedded deposits. But they are stated to have a very different origin. The ores of this class have all been brought into their present position by solution, probably from the Ordovician bedded deposits.

The question of the origin of the breccia ores "has been one of the most puzzling problems encountered in the zinc regions. The only theory for these formations that seems tenable is that of the apparently irregular masses of breccia, that is, the breccias not upon fault and such like fractures, have been formed along ancient underground water-courses."

One of the most suggestive points brought out in this consideration of the zinc ores is the relation of synclines to the presence of ores. Dr. Branner says: "If the hypothetical history here assigned the north Arkansas zinc ores is thus far correct, we are forced to conclude that the geologic structure of the region is of the utmost importance in the determination of the present distribution of the ores. In an elevated region of approximately horizontal or very gently folded sediments, the waters falling upon the ground and soaking into the earth tend to seek the bottoms of the synclinal troughs. The process of ore accumulation in such a region would therefore tend to carry the ores into the synclines. The rocks of the zinc region, although not far from horizontal, are gently folded. Wherever folds have been exposed in the zinc mines the bottoms and sides of these folds have been found richer in zinc than the adjacent portions of the same beds. This is a rule to which I know but few exceptions. The inference seems to be warranted that the synclinal troughs should be located and examined for the richer zinc accumulations."

Of exceptional interest at this time are the notes on the faults of north Arkansas. For the first time in the consideration of the zinc region something tangible regarding these structures and their character is made available. The throw of the faults, though never very great, is sometimes four hundred feet or more. The character of the folds found in the vicinity of the faults is shown by numerous figures.

The illustrations are unusually good.

C. R. Keyes.

Texas Petroleum. By WILLIAM BATTLE PHILLIPS, Ph.D., Director. The University of Texas Mineral Survey Bulletin No 1; 102 pp., plates, maps. Austin, July, 1901.

THE University of Texas Mineral Survey, organized in May, 1901, with Dr. William B. Phillips of the university as director, establishes a new record for expeditious work in official geologic investigation by the timely appearance of this volume on a subject which is attracting much attention within the state and without.

An historical account of the development of the Texas oil fields is followed by a chapter on the nature and origin of petroleum, and other chapters on the oil and gas-bearing formations and the utilization of Texas oils.

The Paleozoic formations are not known to hold oil or gas in commercial quantities. The Cretaceous formation, more specifically the Corsicana field, has furnished practically all of the oil which has been produced until the current year. This field has a well-defined extent of from two to three miles in width by six and one-half miles in length in a northeasterly direction. The oil is reached at a depth of 1,050 feet in a soft, gray, foraminiferal shale. In July, 1901, there were 603 producing wells, with an average daily output of about 3,000 barrels of oil worth 70 cents per barrel. The production of oil in Texas for 1899 was 669,013 barrels, while that for 1900 was 836,039 barrels, almost all coming from this field. The Corsicana refinery has a capacity of 1,500 barrels of crude oil daily. Half the output consists of gasoline and kerosene, the residuum being marketed as fuel.

In the Tertiary, the Nacogdoches field was the first to be discovered, dating from 1867. The oil is found in Eocene strata at depths of 70 to 150 feet, and is a heavy lubricating oil with a high boiling point and non-gumming qualities. No oil has been produced in this region since the early part of 1900.

The Beaumont field has been the center of attraction since January 10, 1901, when the famous Lucas "gusher" was brought in. In July, 1901, there were fourteen producing wells all within an area 1,000 by 2,000 feet on Spindle Top Heights, a low ridge lying about four miles south of Beaumont. The ridge is about one mile wide and two miles long in a northeasterly direction and reaches a maximum elevation of 30 feet above the surrounding prairie. Wells outside the proven area are dry. It is presumed that the ridge marks an anticline, though the structure is not yet known certainly. Concerning the fabulous production of the gushers, no definite figures can yet be given, but the production is unquestionably large. Pipe lines connect the field with tide water at Sabine Pass and Port Arthur where refineries are in process of construction. In quality the oil is a heavy fuel oil, the price of which, in July, 1901, varied from 20 to 40 cents per barrel.

In connection with the origin of the oil, an investigation was made of the so-called "oil ponds," certain quiet spots in the Gulf near Sabine Pass and popularly supposed to be caused by oil escaping from submarine springs. The areas were found to be over extensive beds of black ooze. The examination of samples of this ooze disclosed the presence of sulphur and of diatoms containing oil globules, but of no free oil except such as manifestly came down from the overflow of the Beaumont wells. Sulphur deposits occur over the Beaumont oil horizon. The possible analogy of the present conditions to the conditions prevailing when the Beaumont oil-bearing formation was deposited is suggested as well as the possible connection of diatoms with the oil production.

The report is well printed and illustrated with a number of photographs of characteristic scenes in the different fields, including several of the "gushers" in action, and is in all respects a worthy inauguration of the new survey.

C. E. S.

Lessons in Physical Geography. By CHARLES R. DRYER. American Book Co.: New York, Cincinnati, and Chicago, 1901.

This text-book of high-school grade covers the field of physical geography from the modern standpoint. It has several characteristics for which it deserves recognition as more than a mere variation of what has already been accomplished in other books. It is, first of all, a very concrete presentation of the physiographic principles which have recently come into prominence. Thirty-four pages are given to three typical river systems, the Mississippi, the Colorado, and the St. Lawrence, and thirteen pages to the drift sheet of North America, beside the general treatment of glaciers. The chapters which are devoted to more general subjects also abound in descriptive examples and pictorial illustrations. In the second place, the book has a large number of illustrations which are new to text-books; many of these are drawn from Indiana and neighboring states and will be welcome to teachers as showing that the modern science of physiography does not rest on a few classical examples. The book leaves the very wholesome impression that the United States abounds in valuable illustrations which are yet unknown to text-book literature, the bringing forward of which depends largely upon teachers who are working in their vicinity, just as Mr. Dryer has sought out those of his own state. The arrangement of the book is good for those who may wish to follow the author's own order and convenient for those who do not. The suggestions on method, both in the "Realistic Exercises" and in the appendix, are helpful. The teacher is introduced to many of the valuable materials which are now available for this study. A good bibliography is given. The author is plainly in touch with the most recent work in his science. A few statements or suggestions in geology do not take into account some of the recent work. A sentence on p. 48, despite previous cautious statements, implies the belief that isostacy alone may support the earth's broad plateaus. On the same page the wrinkling of the earth's crust is ascribed solely to cooling of the interior. A faulty impression of slate would be left by the mention on p. 32. Under "Causes of Glacial Motion," three theories are mentioned: plastic flow, regelation, and alternate melting and freezing. Processes which in recent studies have become more prominent than these are not mentioned. The too general and perhaps misleading contrast between the "older drift" and the "newer drift" are not due to any lack of information on the author's part, whose familiarity with the complexity [illegible]ift problems is shown both in this and other writings. An unfortunate expression on p. 135 would leave the impression that the Great Basin as a whole is actually a *basin* with a rim. The mention of "subordinate basins" serves to emphasize this error. Small shortcomings like those mentioned here are but rare exceptions in this very good text-book. In its characteristic qualities the book not only meets the general demands of good science and good teaching, but is well adapted to the particular needs of the present time.

N. M. F.

Some Notes Regarding Vaerdal; The Great Landslip. DR. HANS REUSCH. *Norges geologiske Undersögelse;* Aarbog for 1900.

THIS complete and well illustrated note, which Dr. Reusch has summarized in English, recounts a very remarkable landslip. The level surface into which the river Vaerdal has cut a steep-sided valley is an upland of stratified marine clays, deposited during a submergence of the Norway coast since the Glacial Period. Within these clays was a great mass of "quick clay" not constituting a definite stratum but existing, probably, in more or less definite lenticular masses. A small side stream, the Follo, had cut a short gorge into the quick clays, giving the latter an exit to the main valley. On the night of the 19th of May, 1893, a volume of this semi-fluid clay, estimated at 55 million cubic meters, escaped into the larger valley, inundating it to the extent of eight and one half square kilometers. The collapse occupied one half hour and the advancing front of the mud traveled five or six kilometers in three quarters of an hour. Some of the inhabitants were rescued from the roof of their house after sailing three and a half miles on the river of mud. Over a part of the area the upper layer of clay was firm, and, with the overlying turf, constituted a crust sufficiently strong to remain intact while the quick clay flowed out from beneath. Parts of fields bearing trees were thus dropped vertically downward, leaving the trees standing erect at the lower level. The vertical distance through which the surface fell is not given, but the pictures represent it as many meters and the sides of the pit as quite sheer in many places. The author gives a note, also, on a similar but smaller landslip which occurred on the 16th of August of the same year in the valley of the small stream Graaelven. The finely banded marine clays concerned in this slip are made the basis of a time estimate. Their thickness is taken at fifty meters, and they consist of alternating dark and light layers. On the supposition that one dark layer and an adjacent light layer were deposited in one year, the time consumed in their deposition is estimated at 4,000 years. The proportion of post-glacial time which this represents is not estimated.

N. M. F.

Geological Map of West Virginia. Second edition. I. C. WHITE, State Geologist. Published by West Virginia Geological Survey, Morgantown, W. Va.

THE Geological Map of West Virginia, first published in 1899, has recently been revised and new features added. The map shows in separate colors the three great coal formations of West Virginia, viz., the New River or Pocahontas, the lowest; the Allegheny-Kanawha series in the middle; and the Monongahela or Pittsburg (Connellsville) at the top. Two features not shown on the original map have been added in this edition, viz., the prominent anticlinal lines, and the locations and names of every coal mine in the state shipping coal by rail or river, up to July 15, 1901, the approximate locations of the mines being indicated by numbered black dots, and the corresponding names and numbers printed on the margin of the map by counties. The map shows also oil and gas developments of the state, and should prove of much use to those interested in these subjects. Copies may be purchased (50 cents) from the West Virginia Geological Survey, Box 448, Morgantown, W. Va.

RECENT PUBLICATIONS.

—American Academy of Arts and Sciences, Proceedings of the. Vol. XXXVI, No. 29, June, 1901.

—AMI, HENRY M. Knoydart Formation of Nova Scotia. [Bull. of the Geol. Soc. of America, Vol. XII, pp. 301–312, Pl. XXVI.] Rochester, 1901.

—Atti della Academia Olimpica Di Vicenza. Annate 1899–1900, Vol. XXXII. Vicenza, 1900.

—BARTON, GEORGE H. Outline of Elementary Lithology. Boston, 1900.

—BRANNER, JOHN C. The Zinc- and Lead-Ore Deposits of North Arkansas. [A paper read before the American Institute of Mining Engineers, at its Mexican Meeting, November, 1901.] Author's edition, 1901.

—BUCKLEY, ERNEST ROBERTSON. The Clays and Clay Industries of Wisconsin. [Bulletin No. VII (Part I), Economic Series No. 4, Wisconsin Geological and Natural History Survey.] Madison, Wis., 1901.

—CALHOUN, F. H. H. Early Conceptions Concerning the Earth and Natural Objects. [Reprinted from the Bulletin of the American Bureau of Geography, Vol. II, No. 3, September, 1901.

—CUSHING, H. P. Geology of Rand Hill and Vicinity, Clinton County. [Reprinted from the Nineteenth Annual Report of the State Geologist; University of the State of New York: State Museum,] Albany, 1901.

—DRYER, CHARLES R. Lessons in Physical Geography. American Book Company, New York, Cincinnati, Chicago, 1901.

—DUBOIS, EUG. Les Causes Probables du Phénoméne Paléoglaciaire Permo-Carboniférien dans les Basses Latitudes. [Extrait des Archives Teyler, Séri II, T. VII, Quatrième partie.] Haarlem, 1901.

—GLANGEAUD, M. PH. Monographie du Volcan de Gravenoire Près de Clermont-Ferrand. [Bulletin des Services de la Carte Géologique de la France et des Topographies Souterraines. No. 82, Tome XII, 1900–1901.] Paris, 1901.

—GRANT, ULYSSES SHERMAN. Preliminary Report of the Copper-Bearing Rocks of Douglas County, Wisconsin. [Wisconsin Geological and Natural History Survey Bulletin No. 6 (Second Edition); Economic Series No. 3.] Madison, Wis., 1901.

—HALL, C. W. Keewatin Area of Eastern and Central Minnesota. [Bull. of the Geol. Soc. of America, Vol. XII, pp. 343–376, Pls. XXIX–XXXII.] Rochester, August, 1901.

—Keweenawan Area of Eastern Minnesota. [Bull. of the Geol. Soc. of America, Vol. XII, pp. 313–342, Pls. XXVII, XXVIII.] Rochester, August, 1901.

—Högbom, A. G. Eine Meteorstatistische Studie. Hierzu eine Tabelle und Tafel IV. [Reprinted from Bull. of the Geol. Instit. of Upsala, No. 9, Vol. V, Part I, 1900.] Upsala, 1901.

—Kansas Academy of Sciences, Transactions of the. Vol. XVII, 1899–1900. Topeka, 1901.

—LeRoy, Osmond Edgar. Geology of Rigaud Mountain, Canada. [Bull. of the Geol. Soc. of Am., Vol. XII, pp. 377–394, Pls. 33–34.] Rochester, September, 1901.

—List of the published writings of Elkanah Billings, F. G. S., Paleontologist to the Geological Survey of Canada, 1856–1876. Prepared by B. E. Walker, F. G. S., Toronto, Canada. [Reprinted from the Canadian Record of Science, Vol. VIII, No. 6, for July, 1901. issued 10th August, 1901.]

—Mohr, Charles. Plant Life of Alabama. [Reprint of Vol. VI, Contributions from the U. S. National Herbarium, published July 31, 1901, by the U. S. Dept. of Agriculture. Prepared in coöperation with the Geological Survey of Alabama. Eugene Allen Smith, State Geologist.] Alabama Edition, with portrait and biography of the author. Montgomery, Ala., 1901.

—New York Academy of Sciences, Annals of the. Vol. XIV, Part I. Charles Lane Poor, Editor.

—Pittman, Edward F. The Mineral Resources of New South Wales. Geological Survey of New South Wales; Edward F. Pittman, Government Geologist.

—Prosser, Charles S. The Paleozoic Formation of Allegany County, Maryland. [Reprinted from the Journal of Geology. Vol. IX, No. 5, July–August, 1901.] The University of Chicago Press.

—Reade, T. Mellard. Sand-Blast of the Shore and its Erosive Effect on Wood. [Extracted from the Geological Magazine, N. S., Decade IV, Vol. VIII, pp. 193–194, May, 1901.] Dulau & Co., 37 Soho Square, W., London.

—Reade, T. Mellard, and Philip Holland. The Green Slates of the Lake District, with a Theory of Slate Structure and Slaty Cleavage. [Reprinted from the Proceedings of the Liverpool Geological Society, 1900–1901.] Liverpool, 1901.

—Reusch, Hans. Norges Geologiske Undersögelse, No. 32. Aarbog for 1900. [With English Summary.] Kristiania, 1901.

—Russell, Israel Cook. Geology and Water Resources of Nez Perces County, Idaho, Parts I and II. [Bulletins No. 53 and 54, Water-Supply and Irrigation Papers of the United States Geological Survey.] Washington, 1901.

—**Shimek**, B. I. Pyramidula Shimekii (Pils.) Shim. II. The Iowa Pteridophyta. [Excerpt from the Bulletin of the Laboratories of Natural History, State University of Iowa. Vol. V, pp. 139–170.] April, 1901.

The Loess of Iowa City and Vicinity. Iowa Pteridophyta (Con.). Addenda to the Flora of Lyon County. [Excerpt from the Bulletin of the Laboratories of Natural History, State University of Iowa. Vol. V, No. 2, pp. 195–216.] May, 1901.

—**Stokes**, H. N. On Pyrite and Marcasite. [Bulletin of the United States Geological Survey, No. 186: Series E, Chemistry and Physics, 35.] Washington, 1901.

—**Turner**, H. W. The Esmeralda Formation, A Fresh-Water Lake Deposit in Nevada. With a Description of the Fossil Plants, by F. H. Knowlton, and of a Fossil Fish, by F. A. Lucas. [Extract from the Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part II, General Geology, Economic Geology, Alaska.] Washington, 1900.

—United States Department of Agriculture, Division of Soils, Milton Whitney, Chief. Circular No. 8 :Reclamation of Salt Marsh Lands, Thomas H. Means, Assistant.

Bulletin No. 17: Soil Solutions, Their Nature and Functions, and the Classification of Alkali Lands; by Frank K. Cameron, Soil Chemist, Division of Soils (Coöperating with the Division of Chemistry). Washington, 1901.

Bulletin No. 18: Solution Studies of Salts Occurring in Alkali Soils; by Frank K. Cameron, Lyman J. Briggs, and Atherton Seidell. Washington, 1901.

—Washington Academy of Sciences, Proceedings of the.

Papers from the Hopkins Stanford Galapagos Expedition, 1898–1899. II. Entomological Results (2): Diptera; by D. W. Coquillet, Custodian of Diptera, United States National Museum. Vol. III, pp. 371–379, November 7, 1901.

Papers from the Hopkins Stanford Galapagos Expedition, 1898–1899. III. Entomological Results (3): Odonata. [Text Figures 29–34. By Rolla P. Currie, Aid, Division of Insects, United States National Museum. Vol. III, pp. 381–389, November 7, 1901.

Papers from the Hopkins Stanford Galapagos Expedition, 1898–1899. IV. Entomological results (4): Orthoptera. [Text Figures 35–44.] By Jerome McNeill. Vol. III, pp. 487–506, November 7, 1901.

Synonomy of the Fish Skeleton. [Plates LXIII–LXV. Text Figures 45–46.] By Edwin Chapin Starks, Leland Stanford Junior University. Vol. III, pp. 507–539, November 7, 1901.

Weed, W. H., and L. V. **Pirsson**. Geology of the Shonkin Sag and Palisade Butte Laccoliths in the Highwood Mountains of Montana. [From the American Journal of Science, Vol. XII, July, 1901.]

THE

JOURNAL OF GEOLOGY

NOVEMBER–DECEMBER, 1901

THE FOYAITE-IJOLITE SERIES OF MAGNET COVE: A CHEMICAL STUDY IN DIFFERENTIATION. II.[1]

DISCUSSION.

In the table below are given the chief molecular ratios of those analyses of the Magnet Cove rocks which I am led to believe are the most reliable and representative. There are also

	I	II	III	IV	V	VI	VII	VIII
SiO_2	38.39	38.93	41.75	44.40	49.70	53.09	60.13	60.20
TiO_2	4.54	1.62	0.58	1.53	1.33	0.11	1.15	0.14
Al_2O_3	7.05	15.41	17.04	19.95	18.45	21.16	20.03	20.40
(FeO)	14.33	8.83	9.04	7.41	7.37	3.74	3.45	3.44
MgO	11.58	5.57	4.71	1.75	2.32	0.32	0.76	1.04
CaO	19.01	16.49	14.57	8.49	7.91	3.30	0.87	2.00
Na_2O	0.74	5.27	6.17	6.50	5.33	6.86	6.30	6.30
K_2O	0.75	1.78	3.98	8.14	4.95	8.42	5.97	6.07
MOLECULAR RATIO								
SiO_2	.640	.649	.696	.740	.828	.885	1.002	1.003
TiO_2	.055	.019	.007	.0.18	.015	.001	.014	.002
Al_2O_3	.069	.151	.167	.196	.181	.207	.196	.200
(FeO)	.199	.123	.127	.082	.102	.052	.048	.048
MgO	.290	.139	.118	.044	.058	.008	.019	.026
CaO	.339	.294	.260	.152	.141	.059	.015	.036
Na_2O	.012	.085	.098	.105	.086	.117	.100	.102
K_2O	.008	.019	.042	.087	.053	.090	.061	.065
$\frac{Na_2O}{K_2O}$	1.50	5.00	2.33	1.21	1.62	1.30	1.64	1.57
Specific Gravity	3.407	2.769	3.084	2.770		2.599	2.557	2.642

I. Jacupirangite.
II. Biotite Ijolite.
III. Ijolite.
VI. Arkite.
V. Covite.
VI. Foyaite, Diamond Jo.
VII. Pulaskite, Braddock's quarry.
VIII. Pulaskite, Type, Fourche Mt.

---

[1] Continued from p. 622.

inserted the figures for my two analyses of the Fourche Mountain rocks, which, although somewhat distant from Magnet Cove, undoubtedly belong to the same general regional magma. To render the diagrams less complicated the iron oxides are calculated together as (FeO).

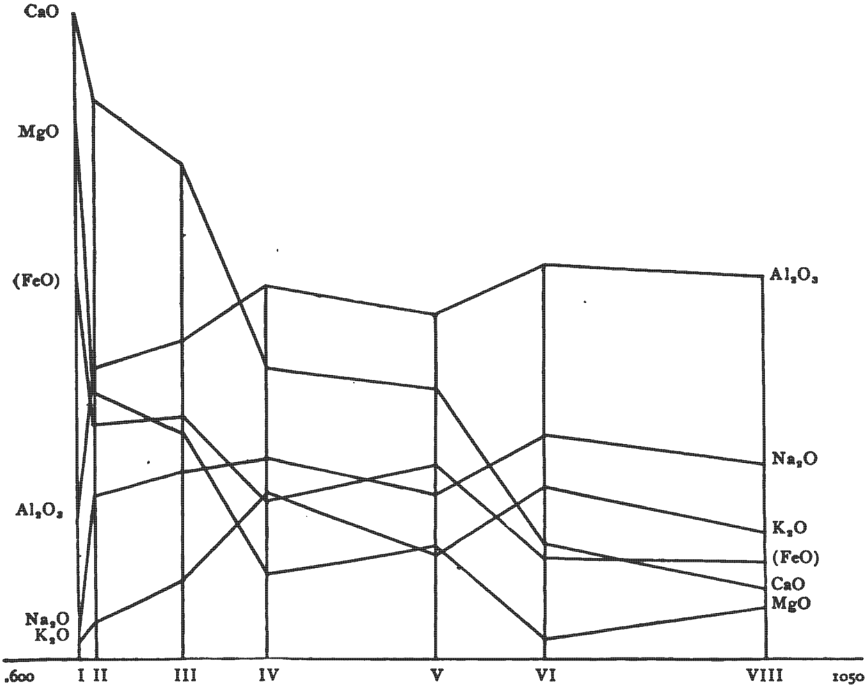


DIAGRAM I.

It has already been explained that at Magnet Cove the arrangement of rocks from center to periphery is regularly serial, from basic to intermediate, *i. e.*, from II to VI. If, therefore, the analyses are plotted according to Iddings's method, using the silica values for the abscissae, the diagram will represent in a general way the variation of this particular magma in space. This was done in my former paper[1] for the earlier analyses, and the results of the present investigation are shown in Diagram I.

---

[1] H. S. WASHINGTON, *op. cit.*, p. 404.

Comparison of the two shows that the curves, or rather zigzags, are much alike even though the analyses of (and consequently the abscissal positions of the figures for) arkite are different in the two. At the same time the new diagram is markedly more broken, and varies less regularly and continuously than the former. The regularly serial character of the first is thus apparently diminished, and what it was thought would be an excellent example of regular differentiation seems to turn out rather the contrary.

But, as Pirsson justly remarks, the use of SiO_2 for the abscissae is arbitrary, and, since this is one of the most important rock ingredients, its variation should also be shown in a manner directly comparable with those of the other oxides.

It would seem to be undeniable that this is a legitimate, indeed a most logical, method if the differentiated mass has not suffered disturbance and if circumstances permit the determination of the correct distances of the various differentiates from the center, since the diagram then represents, not only the compositions of the various phases, but their actual relations in space, both as to direction and as to relative position.

It often happens, as apparently at Magnet Cove, that the successive differentiation products are sharply separated from each other, transition forms being either lacking or very small in amount as compared with the main types. To correspond then with the actual state of affairs, the diagram should consist of steps, *i. e.*, horizontal lines of a length equal to the breadth of each zone, at the respective ordinal positions for each oxide.

Since, however, the analyses may be assumed to represent the average composition of each differentiation product, and we desire to study the course and the laws of differentiation, it is legitimate to represent the position of each constituent by a point, and the lines connecting these will therefore express the course of the differentiation of the mass of magma, even though, as an actual matter of fact, all the possible gradations represented by the curves may not be present. Such a procedure is quite in accordance with the general practice in chemical and physical research, and this point is mentioned only because such methods have, as yet, found little application in petrography.

In order to construct the curves two important field data are required; the position of the center of the mass or area, and the relative distances from this of the various types analyzed.

By center is meant that of the innermost petrographic zone or core, not necessarily the geometrical center of the mass, as this petrographic center may be conceivably geometrically eccentric. Since, in many cases, as here, we have only one section, a horizontal one, this point is not necessarily the center of the mass, but rather its epicenter, to use the seismological term.

Since the area of Magnet Cove forms a fairly regular ellipse with axes of about 5 and 3 kilometers, the center of the igneous area is easily determined. Its position is marked approximately by the Baptist church,[1] which lies in the small central exposure of biotite-ijolite. Inasmuch as we do not know whether the plane of the present exposed area cuts the mass centrally or above the center, we cannot tell whether the central point of this is the true center of differentiation or not. It is probably not so. But as far as the types exposed are concerned this is of little moment, as their mutual relations would remain the same, or approximately so, in any case.

Having determined the center the next point is to determine the distances of the various types from this. It is obvious that for the proper plotting of the curves, and hence the study of the course of differentiation, this is of great importance, since the points which determine the various curves will be shifted in one direction or another according to the distances selected. This would alter very materially the slope of the curves, and even their character or shape, as by the shifting of the abscissal positions a straight line will become a curve, or a simple curve of the second degree may assume the form of an inflexed one of the third.

At Magnet Cove we cannot determine the abscissal positions by simply measuring the distances from the center to the particular spots where the analyzed specimens were collected, because, owing to the elliptical shape of the area, a specimen (*e. g.*, covite) from near the end of the major axis may be at an actually greater distance from the center than one (*e.g.*, foyaite) from the end of the minor axis, though genetically inside the latter.

---

[1] *Cf.* the maps in papers already cited.

It would, of course be best to have several analyses of each type from different parts of the zones, both radially and circularly, so as to get the mean composition of each. But as that involves the making of very many analyses, we must be content at present with selecting what seem to be representative specimens, and assume that their analyses correspond to the average composition of each type.

Assuming this, two courses are open to us. We can either measure the distances from the center along a radial line on which all occur, or average the distances of the various occurrences of each type. The latter has been the process adopted here, since it seemed more likely to eliminate errors due to local conditions.

For each type measurements were made on Williams's map in many directions from the Baptist church to the middle point of each zone exposed, and the mean of these taken in each case. On the diagrams the abscissal positions of III, IV, V and VI, from the origin at II represent these relatively, as it is not necessary that the diagrams be of the same scale as the map. The position of the foyaite (VI) is not fixed as accurately as those of the others, since, being at the periphery, it is in great part overlaid by the surrounding shales. Small outcrops outside the main area, however, allow a rough estimate of its average distance, though it undoubtedly extends farther away from the exposed area than the few outcrops indicate.

In my former paper I assumed that the petrographic center of the area was in the "magnetite bed," and that this was the result of the decomposition of underlying jacupirangite. As, however, this is quite uncertain, it seems best for the purpose in view to disregard this area. For the present then the analysis (and the diagram position) of the jacupirangite may be neglected. The same is true of the pulaskite analyses, these rocks lying quite outside the Magnet Cove area. All these rocks will be discussed subsequently.

We thus obtain the result shown in Diagram 2, where the points are connected by straight lines. In this, and the following, the vertical scale for SiO_2 begins .400 lower than the others, so as to condense the diagram and at the same time preserve the relative forms of all the curves (given later), and not flatten that of silica, as would be done if a smaller vertical scale were used for this than for the other constituents.

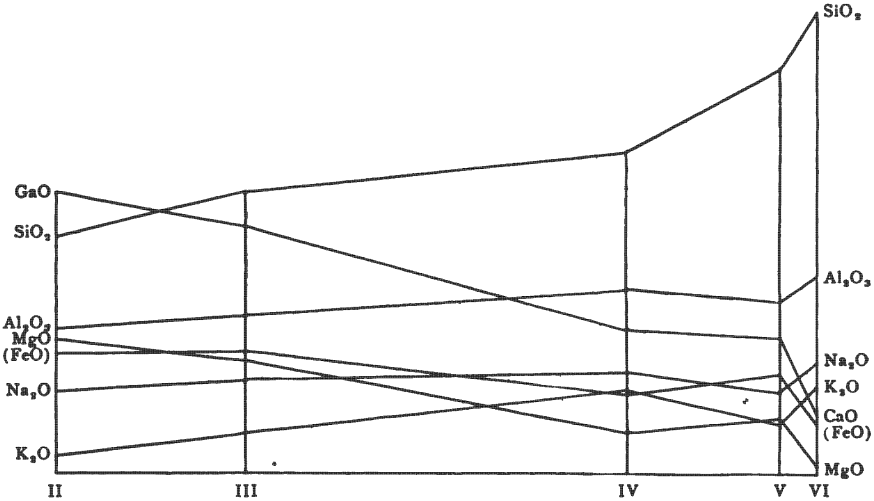


DIAGRAM 2.

When Diagram 2 is examined it is clear that, with the exception of the values for covite (V), all the points of the respective oxides lie along very smooth curves. For convenience in further discussion the curves formed by the figures for II, III, IV and VI are plotted separately in Diagram 3. The values for V (covite) are entirely omitted from this, and the position and relationships of this rock will be discussed later on. The curves marked *F* and *M* will also be explained presently. All the curves, it may be mentioned, were drawn with a spline, so that the personal equation is eliminated as far as possible.

Within the limits from II to VI the curves are simple, that of SiO_2 alone showing inflexion about at the center of the diagram, rising sharply toward the right (acid end) and falling gently toward the left (basic end). Most of the curves are quite flat, especially those of Al_2O_3, Na_2O and K_2O, which approximate straight lines. At the same time they are all distinctly curves and not strictly linear.[1] It will be remembered that Pirsson[2] says that all of the lines of his diagram should probably be drawn as very flat curves (much flatter than these), and these observations are in accordance with the conclusion of Harker,[3] that strictly linear series of rocks are of rare occurrence.

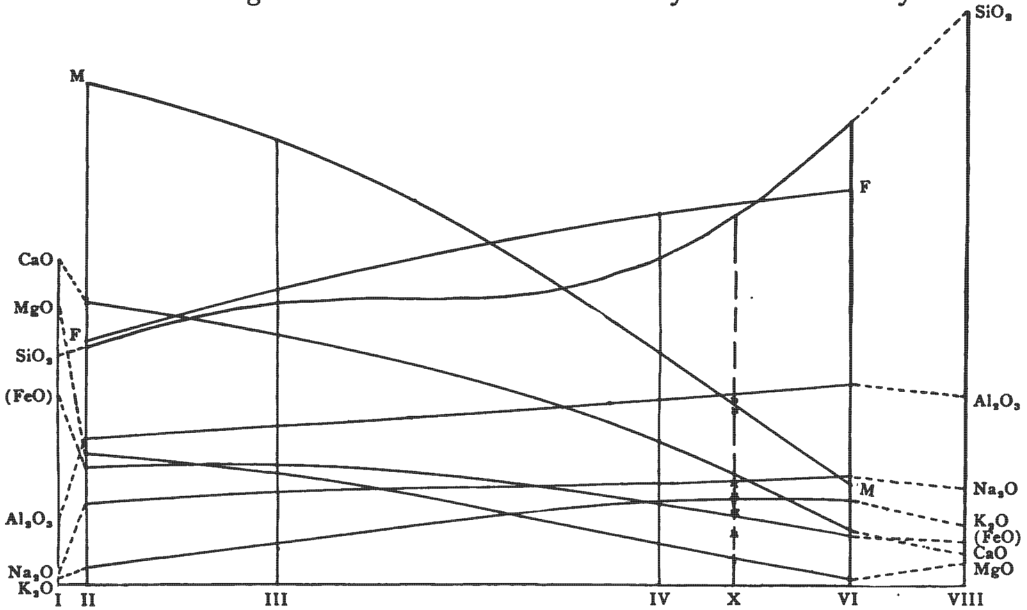


DIAGRAM 3.

With the exception of SiO_2, which is inflexed and that of

---

[1] This is best seen in the large-scale drawing from which the diagram is reproduced.

[2] L. V. PIRSSON, *op. cit.*, p. 571.

[3] A. HARKER, JOUR. GEOL., Vol. VIII, p. 392, 1900.

Al_2O_3, which is almost a straight line but slightly convex,[1] all the curves are concave[1] (toward the bottom).

The curves divide themselves naturally into two groups, according to general direction. Those of SiO_2, Al_2O_3, Na_2O and K_2O ascend toward the right (the periphery), the three last almost arithmetically. It will be noticed that the K_2O curve ascends more rapidly than that of Na_2O to a point a little to the right of IV, when it drops a trifle more rapidly. This is expressed in the series of the ratios of these two oxides, already given in Table I. The second group is that of (FeO), MgO and CaO, which descend toward the right, and at a greater rate than those of the other group rise, SiO_2 excepted.

It may be noted, by the way, that if TiO_2 be plotted with SiO_2, the curve of the sums of the two becomes rather more flat (especially about IV), and the inflexion at the left is almost overcome. For facilitating this observation I have put the molecular ratios of TiO_2 next to those of SiO_2 in the table, though it would complicate the diagram unnecessarily to put in this joint curve. This seems to confirm the general belief that TiO_2 plays the part of an acid radical, like SiO_2, in rock magmas.

The general results can be concisely shown by plotting the sums respectively of the "ascending" and the "descending" oxides, except silica. We then get the two curves *F* (that of Al_2O_3, Na_2O, K_2O) and *M* (FeO, MgO, CaO), on the line of which all the determining points fall very exactly. They are both decidedly concave, *F* ascending and *M* descending, and their smoothness and regularity are very striking.

These results are in strong harmony with those of Pirsson, and the general characters of the curves in each diagram are very similar, though there are some differences in detail. Thus all his curves are much flatter, the SiO_2 does not show signs of inflexion, and the Al_2O_3 is concave and K_2O convex, while in mine these two are reversed. But these are small matters, possibly due to the abscissal distances at Yogo Peak not being as easily ascertainable as at Magnet Cove. The general conformity of the two is very good evidence to show that, if plotted according to their spacial (*i. e.*, genetic) relations in the mass, the analysis of the components of an igneous complex will furnish regular curve. This fact is almost proof positive of the view that the variation of rocks is due to differentiation of some sort.

---

[1] The terms convex and concave will be understood as referring always to the *X* axis, the bottom of the diagram.

Whether this differentiation is always as is now believed, viz., that the oxides of Al, Na and K tend to segregate in one direction, while those of Fe, Mg and Ca segregate in another, as well as the process by which these changes are brought about, are separate questions, which further investigation must settle. It may be that the general course indicated by the diagrams of Pirsson and myself are typical of all rock differentiation, or it may be that with magmas of different character the course of differentiation may be radically different, and that the same oxides do not always tend to go together.

At any rate, it may be confidently expected that where a mass of magma has been differentiated *in situ* and is of approximately regular shape, has not been subjected to secondary disturbing conditions, and the exposures sufficient, we can express the relations of the differentiation products and the course of differentiation mathematically, as has been done in these two instances. Of course, for this purpose, it is absolutely essential that the analyzed specimens be representative, and that the analyses be complete and accurate. Otherwise the curves will be misleading or else uneven zig-zags, only rough approximations to the truth, and possibly not even that. There must also be present at least three differentiates, as otherwise only straight lines connecting the two can be drawn.

The fact that the SiO_2 curve is the only one which is inflexed, and that it runs very sharply up toward the acid end, leads to some interesting conclusions. Since, toward the acid end, the curves of (FeO), MgO and CaO drop much more rapidly than those of Al_2O_3, Na_2O and K_2O, it is evident that at a short distance to the right (in other words with a slight increase in silica), they will practically disappear if the differentiation continues as indicated by the body of the diagram. Further differentiation in this direction then would lead to the production of a purely feldspathic or feldspathoidal rock. If continued still further quartz (free silica) would appear and the rock become aplitic in character. Finally, since the silica is increasing at a rapid geometrical rate, while the other constituents are dropping, the extreme result of differentiation in this direction would be pure quartz.

This inference is obviously in line with the experiments of Barus and Iddings[1] which indicated that in igneous magmas SiO_2 plays the rôle of electrolytic solvent, analogous to that of H_2O in aqueous solutions. This result is also in harmony with the experiments and conclusions of Lagorio[2] and Morozewicz,[3] who come to the conclusion that the predominant magmatic solvent is composed of silica and alkalis, and that it has the power of dissolving large amounts of alumina. The results obtained above would indicate that alumina itself is an essential constituent of the solvent, and it would also seem that there need be no stoichiometrical ratio between the four constituents. As has been indicated above, however, it will not do to push conclusions too far from such meager data, and it is by no means necessary to infer that a rock solvent of this character is the only possible one. But it will be as well to defer all discussion of these topics until more complete data are available.

The comparative rarity of occurrences of purely or very highly siliceous igneous rocks may presumably be ascribed to the fact that long before this phase of differentiation has been reached, the mass will, in most cases, have become solid (owing to the high melting point and great viscosity of such mixtures), and hence incapable of further change in this way.

It is of interest to note in this connection that a specimen of "aplite" has been collected by Dr. Weed, and is now in the

---

[1] BARUS and IDDINGS, *Am. Jour. Sci.*, Vol. XLIV, p. 248, 1892.

[2] LAGORIO, *Min. Pet. Mitth.*, Vol. VIII, p. 508, 1887.

[3] MOROZEWICZ, *Min. Pet. Mitth.*, Vol. XVIII, p. 235, 1899.

United States Geological Survey Reference Collection (No. 813). It is of a small dike, about one and a quarter inches wide, cutting the shale near Neusch's gulley, which it has metamorphosed. I am indebted to Dr. Ransome for the examination and description of this specimen which he sent at my request. "Under the microscope, the dikelet is seen to consist almost wholly of cloudy alkali-feldspar, with no quartz or nephelite, and a little biotite. With high power, the feldspar (between crossed nicols) all shows the fine shadowy striping indicative of a soda-bearing feldspar." Two garnets also occur at the borders of the dike. The occurrence of this aplite dike is clearly corroborative of the view of the course of differentiation which has been just expressed, and it is probable that further search would reveal others which have heretofore escaped notice.

Turning to the other end of the diagram, there is good ground for the belief that there must be inflexion upwards of one or more of the curves beyond II to the left. If the curves are extrapolated to the left, at a distance, let us say, equal to that between II and III, the sum of the constituents reduced to precentages amounts to only 55.6.

It is obvious therefore, either that some other component of the magma than any of those plotted is greatly concentrated at the basic end, or else that the curves of one or more of the plotted constituents must run very sharply upward, thus causing inflexion.

In the former case a probable additional constituent would be P_2O_5, which would yield, with high CaO, MgO and (FeO), an apatite-rich pyroxenite like that of Ahvenvaara in Finland,[1] or with disappearance of SiO_2, an apatite-magnetite rock like that of Alnö.[2] If TiO_2 should be the constituent to assume extraordinary proportions toward the basic end, we would expect, with disappearance of SiO_2, titaniferous magnetites, or such rocks as the magnetite-perofskite rock of Brazil, described by Derby.[3]

---

[1] V. HACKMAN, *Bull. Com. Géol. Finl.*, No. XI, p. 36, 1900.

[2] *Cf.* ROSENBUSCH, *Elemente*, No. 3, p. 133, 1898.

[3] O. A. DERBY, *Neues Jahrb.*, 1894, Vol. II, p. 297.

Such products are, however, very exceptional, and are only to be expected in cases of very complete differentiation. In general we would only look for sharp upward inflexions of the (FeO) and MgO curves, which would yield, with the slowly dropping silica and the high CaO, a pyroxenite rich in magnetite. This is just the character of the jacupirangite of Magnet Cove (I), and of those of Brazil and Alnö, and I have indicated its connection with the others accordingly by the dotted lines to the left.

Inasmuch as the specimens of this come from a small isolated mass outside the main area, its relations to the other types are uncertain, and its diagrammatic position has been given on the basis of its silica content. It seems to be probable that if, as is likely, such a rock is connected genetically with the others, its abscissal position should be considerably more to the left. As this rock is met with in the immediate vicinity of the main area, and is a theoretically possible differentiation product of the magma, it seems reasonable to assume that the section at Magnet Cove cuts the mass some distance above the center, and that below the biotite-ijolite is a core of jacupirangite, as previously supposed.

It is obvious from the theoretical discussion, as well as from observations here and at similar regions, that the relations toward the basic end are far more complex than at the acid end. This arises from the fact that the oxides involved here are capable of more numerous mineralogical combinations, and also because elements which are only present to a small extent in the body of the magma may here assume proportions of great importance. The fact that these extreme basic differentiation products are far more common than the purely siliceous ones may be ascribed to the greater fusibility of magmas of a basic character, and the consequent possibility of differentiation among them at temperatures when the more acid end of the series is solid.

In this connection attention may be called to the fact, analogous to the segregation of TiO_2 and P_2O_5 at Magnet Cove and Brazil, that in large steel castings, such as those for modern artillery, etc., there is a very marked concentration of "impurities," as phosphorus and sulphur, toward the center of the mass.

As all the curves are so smooth and well defined, it seems highly probable that equations for them could be found and that their properties as such could be discussed. In this way we could get at an exact knowledge of the law of differentiation, in this particular case at least. It is a matter of regret that I am not mathematician enough to do this, but there are other applications of the data at hand which are capable of simple mathematical treatment.

Since the area of Magnet Cove is a fairly regular ellipse, and the zones of the various types are concentric about the center, by taking the average distance of each we practically reduce the ellipses to circles, the average distances being the radii.

Now, since II is at the center, if we suppose Diagram 3 to be revolved about the vertical line at II as an axis, it follows that the solids of revolution so generated by each of the curves (with the bounding lines at the sides and bottom), will represent the amount of each oxide in the original magma, and that their sum will represent the composition of the magma as a whole, before differentiation.

This is not strictly true, since we are ignorant of the exact shape and extent of the complex, but as a first approximation and an illustration of the method, it will be of interest to calculate the results which are obtained on this basis. As a matter of fact, the recent description of the Shonkin Sag laccolith by Weed and Pirsson[1] renders it extremely probable that the foyaite is present in far greater relative amount than the surface exposures indicate. This would necessitate a very considerable correction, but, as we have no means at present of estimating this, it will be as well to give the figures based solely on the field observations, leaving possible corrections for the future.

The process of calculating the various volumes is very simple in theory, but somewhat complicated and laborious in practice.

---

[1] WEED and PIRSSON, *Am. Jour. Sci.*, Vol. XII, p. 1, 1901.

As it is a somewhat new departure in petrography it may be of use to others to outline the method which I have employed. The curves shown in Diagram 3 were plotted on paper ruled in inches and tenths. The particular scale is simply a matter of convenience, and it is not necessary to reduce the percentages to 100, as we are dealing with relative amounts.

The formula employed is well known, being the second of Guldin's theorems, viz., the volume of the solid generated by the revolution of a closed curve or plane figure about an axis in its plane, but exterior to itself, is equal to the product of the area of the generating curve into the path described by the center of gravity of the revolving area.

$$V=2\pi rA,$$

where V is the volume, r the distance from the axis to the center of gravity, and A the area of the plane figure.

The areas of the curve, *i. e.*, of the space embraced within the curve itself, and the limits of the diagram, are easily found, either by counting the squares, or by calculation of the area of the trapezoids formed by the respective chords and the limiting lines, and addition to these of the areas embraced between the chords and the curves.

The centers of gravity are found by dividing the trapezoids into two triangles, and finding their centers of gravity, when the center of gravity of the trapezoid will be at the intersection of the line connecting the centers of the two triangles and one connecting the middle points of the two parallel sides. In the case of the more curved lines a correction must be made for the area between the chord and the curve, but this will always be small. SiO_2 was regarded as composed of the large rectangle from .400 below the bottom of the diagram to .249, and the space between this upper boundary and the inflexed curve.

The resultant volumes, being based on the molecular ratios, have to be multiplied by the molecular weights of the respective oxides, in order to arrive at the percentage composition of the whole. In this way I obtained the following figures, which are given in full to illustrate the method.

	A	r	V	V × mol. wt.	Percentage	**Mol. Ratio**	
						Found.	Calc.
SiO_2	52.0	4.	1306.2	90576.0	47.24	.787	.787
	6.0	5.4	203.4				
Al_2O_3	14.0	4.25	375.7	38321.4	19.99	.196	.201
(FeO)	8.25	3.5	181.0	13032.0	6.80	.094	.074
MgO	5.9	2.9	107.4	4296.0	2.24	.056	.029
CaO	16.2	3.5	356.1	19941.6	10.40	.185	.117
Na_2O	8.1	4.1	208.6	12933.2	6.75	.109	.110
K_2O	8.8	4.75	134.2	12614.8	6.58	.070	.090
					100.00		

Of the Magnet Cove rocks this resembles most that of arkite (IV), especially as regards Al_2O_3, (FeO), MgO, and Na_2O, though it is distinctly higher in SiO_2 and CaO and lower in K_2O. Referring it to Diagram 3, its position established by means of SiO_2 is shown at *X*, and the points where this vertical is cut by the oxide curves are the "molecular ratios calc." of the table. The small crosses along the vertical indicate the positions of the various oxides as found. They can be identified by the values in the table.

It will be observed by reference to the diagram or to the last two columns of the table, that in the case of oxides whose curves are approximately straight lines, as Al_2O_3 and Na_2O, the found and calculated values coincide, while in the case of oxides yielding decided curves the value found is below that calculated.

This is in accordance with the demonstration of Harker[1] that if a series be linear the admixture of two or more members will produce a rock having the composition of a possible member of the series, while in a curvilinear series the mixture will not correspond to a possible member.

Another method for arriving at the composition of the magma as a whole would seem to be furnished by the determination of the mean point of each of the curves, thus giving the average composition. If the equations of the various curves were known, these could be calculated mathematically. But for practical purposes it can be done by determining, for each oxide, the ordinal value for each successive tenth of an inch, and taking the mean. The result of this process is given in II below, that given by the previous process being given in I.

---

[1] Harker, Jour. Geol., Vol. VIII, p, 394, 1900.

	I	II
SiO_2........	47.24	45.44
Al_2O_3......	19.99	19.06
(FeO).......	6.80	7.75
MgO........	2.24	3.31
CaO........	10.40	11.81
Na_2O.......	6.75	6.37
K_2O........	6.58	6.26
	100.00	100.00

The two agree fairly well, and are of the same general character, though there are marked discrepancies, II being decidedly more basic in all respects than I. What may be the explanation of this, I am not mathematician enough to say. But the general agreement would indicate that one of the two, or their mean, cannot be far from the truth, *i. e.*, as near as the data at hand permit of approximation.

It is of interest to note that I have been unable to find the analysis of any rock which agrees at all closely with either of these two results. Those which are as high in alkalis being lower in bivalent oxides, while those which agree in this respect are lower in alkalis and alumina. Whether this indicates that there are serious sources of error in the method employed, or else that some undifferentiated magmas may possess chemical compositions not corresponding to those of rocks as yet known, is a question which cannot be decided here. It would seem as if there were nothing *a priori* contrary to the latter hypothesis.

In this connection Harker's[1] remark may be cited: "Given a series such that its diagram has markedly curved lines, the result of the admixture of two members may be something not only foreign to the series, but highly peculiar by comparison with igneous rocks in general." It is true that Harker was discussing the case of the mixture of two members of a series, but differentiation and admixture (of two members of a series) may to a certain extent be regarded as inverse processes, so that the occurrence of a magma of this anomalous composition need not occasion surprise. Being rich in both of the generally antagonistic groups of oxides, it would be especially liable to differentiation. The general lability of the monzonitic magmas as regards the conditions controlling crystallization has been pointed out elsewhere.[1]

---

[1] HARKER, *op. cit.*, p. 395.

The general chemical composition can also be calculated by the relative volumes of the various phases, which has been the only method heretofore available. This would seem to be far more uncertain than the new method, which is based on the mathematical course of differentiation, since the ignorance of certain data may affect the result very seriously. Thus we cannot tell where the boundaries between two zones really fall, and (beneath the hornstone ridge especially) whether there may not be a zone of transitional material.

Assuming that the limits come half way between zones, and that they are of uniform thickness in all directions, we can easily

	Volumes	Weights
II	0.14	0.15
III	8.64	9.85
IV	38.27	39.15
VI	52.95	50.85
	100.00	100.00

SiO_2	50.02
Al_2O_3	20.89
(FeO)	5.87
MgO	1.36
CaO	6.89
Na_2O	6.86
K_2O	8.10
	100.00

---

[1] F. L. Ransome, *Am. Jour. Sci.*, Vol. V, p. 370, 1898. H. S. Washington, Jour. Geol., Vol. V, p. 376, 1897.

calculate the volumes of the several spherical shells, which must also be assumed to represent the true ellipsoidal ones. The results are given below, including the relative volumes and weights (obtained by correction of the former for specific gravity), and the average composition deduced from this latter.

This result is notably less basic than the former calculated from the curves, and approaches somewhat closely to the compositions of the foyaite and the arkite, though in a general way intermediate between the two. This is so, since these two form (on this basis) 90 per cent. of the whole. It must be remembered, however, that this method is not based on curves, but on a succession of steps, and that the influence of the greater width of the more acid phases is intensified by their greater distance from the center. At the same time both methods indicate a magma rich in Al_2O_3, CaO and alkalis, low in SiO_2 and MgO, and with moderate iron.

Inasmuch as there must be a (probably rather large) correction made for the greater mass of foyaite, on the analogy of the Shonkin Sag laccolith, all these figures can, for the present, be regarded as only suggestive and illustrative of the method of investigation proposed, than representing exactly the actual state of affairs.

It is of course hazardous to theorize on such limited data as are yet available, but the methods indicated in Pirsson's paper and the present one would seem to be of not uncommon applicability, and well worth further trial in the investigation of other favorable localities. Indeed, as Pirsson has remarked,[1] "it would seem as if this should be the point of departure in the study of other series." The methods indicated certainly put the study of rock differentiation upon a purely mathematical basis, which in the hands of a competently mathematical petrographer, should surely lead to an exact quantitative knowledge of the laws which control this, and very probably, with the aid of physical chemistry, to a knowledge of the rationale of the process.

[1] PIRSSON, *op. cit.*, p. 576.

In my former paper I suggested as an explanation of the exceptional character of the Magnet Cove and Umptek laccoliths, in having the borders more acid than the centers, that the arrangement depended on the general chemical character of the undifferentiated magma. The process of differentiation was conceived to be, at least for such small bodies, in great part, a sort of fractional crystallization, the magma being regarded as a solution, so that, in accordance with the laws of cooling solutions, the solvent (*i. e.*, the portion present in excess) crystallizes out first around the borders on cooling of the mass.

From what has been learned of the composition of the magma, it is evident that, even though low in silica, it was originally of a decidedly leucocratic character. In other words, the potential feldspathic and feldspathoidal constituents predominated very largely over the calco-ferromagnesian. This is seen plainly from the relative weights of the spherical shells, but even the more basic composition derived from the curves shows the same thing. Thus the composition with 47.24 per cent. of SiO_2 may be obtained approximately by several different mixtures of all or some of the types analyzed, but in every case it necessitates taking from six-tenths to eight-tenths of foyaite, or foyaite and arkite. It seems scarcely necessary to give these calculations, which are purely empirical. The same composition may also be reduced to mineralogical composition in several ways, according to the assumptions made, but here, also, we get about two-thirds of leucocratic minerals.

The original body of magma, then, at Magnet Cove was, notwithstanding its low silica, decidedly leucocratic, as demanded by the theory, so that the alumina and alkalis, with the proper amount of silica for the formation of feldspar and feldspathoids, playing the rôle of solvent, would crystallize first, and hence form the outer portion of the mass.

The latest paper by Weed and Pirrson, already cited, is of great interest in this connection. Here it is shown conclusively that in the well-dissected Shonkin Sag laccolith the outer melanocratic shonkinite is present in enormously greater quantity than the core of syenite, which, though basic, is distinctly leucocratic. The composition of the whole, then, would be melanocratic, as demanded by the theory, though with notable amounts of alkalis and alumina. The same general relations are assumed by analogy for the previously described Square Butte laccolith, whose magma thus possessed a similar strongly melanocratic character, *i. e.*, with a basic "solvent" portion, as was suggested.[1]

In this connection attention may be called to two other examples of differentiated masses in which the borders are more acid than the center. One is the igneous area at Alnö,[2] which is of special interest, since the rocks of this locality are very much like those of Magnet Cove. Another example is that of the Rieserferner massif in the Tyrol as described by Becke.[3] The central part of this is a typical tonalite, while the borders are composed of what is called "Randgranit." Although, unfortunately, no analyses are given, it is very evident from the descriptions and from the separations by heavy solutions that the border rock is decidedly higher in alkalis (especially potash) and silica than the main central mass.

Another region which offers close analogies in many ways with that under discussion is that of Ice River, in British Columbia, the rocks of which, collected by Dr. G. M. Dawson, have been briefly noticed by A. E. Barlow.[4] As the specimens were collected on a hasty trip, nothing is as yet known of their mutual relations in the area, but they form an unbroken series "from the most basic ijolite containing 36.988 per cent. of silica, to ordinary nepheline and sodalite syenites containing 53.638 per cent. of silica." Through the kindness of Dr. Barlow I have been able to examine sections of the ijolite, and it is interesting to note that, while closely analogous to the ijolites of

---

[1] H. S. Washington, *op. cit.*, p. 411.

[2] Högbom, *Afh. Sver. Geol. Unders.*, No. 148, 1895. Map II. This is explained by Högbom as due to melting and absorption of the surrounding gneiss.

[3] F. Becke, *Min. Pet. Mitth.*, Vol. XIII, p. 379, 1893.

[4] A. E. Barlow, *Science*, N. S., Vol. XI, p. 1022, 1900.

Finland and Magnet Cove in most respects, yet that here hornblende replaces augite, thus differing from other known occurrences of this rock. It seems probable that these rocks are not as rich in lime as those of Magnet Cove, but higher in MgO and FeO.

In regard to the possible fourth type of laccolithic differentiation, which was mentioned in my previous paper, namely, that with a gabbroitic or peridotitic or pyroxenitic composition, the suggestion may be advanced here that representatives of this are to be found in the numerous sheets and dikes of diabase, which, as is well known, seldom show marked differentiation between the borders and the center. This is in accord with the view that in these masses the "basic" solvent is present to the almost total exclusion of the feldspathic portion.

As Pirsson has already pointed out,[1] the viscosity of the magma has an important bearing on the form assumed by an intruded mass. The highly viscous acid magmas will tend to arch up the overlying strata and form high laccoliths, while the more fluid, basic magmas do not possess sufficient viscosity to do this in general, and will hence form relatively thin intruded sheets. But, at the same time, many of these sheets are of thickness sufficient to allow of differentiation, if that had been possible through the composition of the magma.

Such sheets, then, may be regarded as the basic homologues of the acid, undifferentiated laccoliths of the Mt. Henry type, differing in form, but like them in that the solvent is largely in excess in the magma, and hence not susceptible to differentiation.

The abnormality of covite has been briefly noted, and a few words must be devoted to it before bringing this paper to a close. It will be observed on reference to Diagram 2 that for this rock the positions of SiO_2, Al_2O_3, Na_2O, and K_2O are below the corresponding abscissal points of the "normal" curves, while those of (FeO), MgO, and CaO are above. In other words, the positions of all the constituents of covite are consistently inversions of what may be called the normal (for Magnet

---

[1] L. V. Pirsson, *Eighteenth Ann. Rep. U. S. Geol. Surv.*, Pt. III, p. 586, 1898.

Cove); where the curve actually ascends, these would cause it to descend, and *vice versâ*.

Three explanations may be advanced for this. The first is, assuming that the covite is a primary differentiation product like II, III, IV, and VI, that the course of differentiation was not regular, but subject to comparatively large variations of an irregular character. This seems to be unreasonable *a priori*, and is also rendered untenable by the great regularity of the curves, if this type be left out of account, by the fact that the abnormalities are systematic in direction, and correspond inversely to the general characters of the respective "normal" curves, as well as by the field relations of this rock.

Another explanation is that the covite is a mixed rock, produced by the combination of either two differentiates of the magma, or one of its differentiates with foreign rock. That it cannot have been produced by mixture of arkite and foyaite is clear from the fact that many of its constituents are not intermediate between those of these two. It might have been produced by a mixture of foyaite and either ijolite or biotite-ijolite though its position in the complex militates strongly against this view. That it is not due to a mixture of the magma, or parts of it, with the country rock is evident from the composition of the latter, which is too low in MgO and CaO to form covite from foyaite, and too poor in alkalis to form it from the more basic members. Its position in the mass, between the foyaite and arkite, not on the extreme border, is also adverse.

The last, and most probable, hypothesis is that the covite is not the result of the primary differentiation which produced the other types, but of a secondary differentiation of one of the differentiaties of the primary process. In such a further differentiation we would expect the same oxides to differentiate in directions like those of the primary process, but in an intensified degree. This, in the case of the more basic of the two complementary secondary differentiates, would give rise to just the abnormalities noted in regard to covite.

Of just what particular phase of the primary differentiation this secondary differentiate is a product it is a little difficult to say, but the evidence of Williams's descriptions, my own observations, and the mineralogical and chemical data, indicate that it was the foyaite sub-magna (VI) which has undergone this further change.

If this view be correct there must exist a complementary differentiate, a rock in which the positions of the various oxides are, as regards the "normal" curves, inverse to those of covite. That is, the loci of silica, alumina, and the alkalis would be above, and those of iron oxides, magnesia, and lime would be below, the "normal."

Whether we actually find this rock or not is more or less an accidental matter of erosion, etc. But a chemical analysis indicates that such exists in the case of the "foyaite" which occupies the small area in the northeastern part of the main mass, which was erroneously colored as ijolite on Williams's map.[1] This is a white, coarse-grained, holocrystalline rock,

	I	II	III	IV	Ia
SiO_2	53.54	53.09	49.70	53.11	.892
Al_2O_3..........	23.95	21.16	18.45	23.62	.234
Fe_2O_3	1.11	1.89	3.39	1.36	.007
FeO	1.24	2.04	4.32	1.47	.017
MgO...........	0.08	0.32	2.32	0.33	.002
CaO	0.71	3.30	7.91	1.51	.012
Na_2O	8.62	6.86	5.33	8.25	.139
K_2O	8.87	8.42	4.95	8.43	.094
H_2O (110°+)...	1.09	1.13	1.09	....	....
H_2O (110°−)...	0.14	0.24	0.25	....	....
CO_2	0.20	0.82	none	....	....
TiO_2...........	trace	0.11	1.33	....	....
P_2O_5	....	0.15	0.40	....	....
Other constituents	....	0.95	....	1.82	....
	99.55	100.48	99.44	100.00	

I. Foyaite, northeast part of area.
II. Foyaite, Diamond Jo quarry.
III. Covite, schoolhouse, western part of area.
IV. Mixture of eight parts of I, and one of III.
Ia. Molecular ratios of I.

---

[1] *Cf.* H. S. WASHINGTON, *op. cit.*, p. 394, note.

composed of alkali feldspar, with nephelite (partly altered to cancrinite), and rare grains of aegirine-augite. The position of this, outside the zone of arkite, is where we would look for such a differentiate of the foyaite magma.

The analysis, made by myself, of this rock is shown in I above, those of the primary foyaite and the covite in II and III, the molecular ratios of I being given in Ia, for comparison with those of the others on a preceding page. It will be seen that the values obtained for the main Diamond Jo foyaite, which is quite typical of this rock found around the border, are intermediate in every case between those for the other two rocks. Reference to Diagram 2 will also make evident the fact that the positions of the various oxides would be, as regards the normal curves, exactly the inverse of those of the covite. The figures for the new analysis fall above or below their respective curves, where those of covite are below or above. This is just what would be expected in the case of secondary differentiates, as has been explained above.

The results of a mixture of eight parts of I and one part of III are shown in IV. It approximates fairly well to the composition of the typical foyaite, especially in SiO_2, MgO, and K_2O, though Al_2O_3, and Na_2O are considerably higher, and iron oxides and CaO lower.

It may be of interest to give the calculated mineralogical composition of I, which works out as follows:

Orthoclase - - - -	52.3
Nephelite - - - -	36.9
Cancrinite - - - - -	2.8
Aegirite - - - -	3.2
Diopside - - - - -	3.7
Extra alumina - - -	1.0
	99.9

The possibility of a secondary differentiation taking place in a primary differentiate is, it must be conceded, difficult to reconcile with the hypothesis already advanced, since according to this the differentiation takes place by a successive crystallization, *i. e.*, solidification of the magma, and any such process is, of course, impossible in a solid mass of rock.

This difficulty, however, does not seem to be insuperable. The evolution of heat on the solidification of molten lava is a well-known phenomena, having been actually observed, and the same has been experimentally verified, and the amount of heat evolved on the solidification of diabase has been determined by Barus.[1] Therefore the crystallization of minerals from a molten magma is an exothermic change.

It is therefore conceivable that the solidification of a laccolithic mass may give rise to sufficient heat to remelt portions of it, which might easily remain liquid long enough for a secondary differentiation to take place. That this was actually the case at Magnet Cove cannot be definitely shown, but it is at least an explanation which has a certain degree of probability in its favor.

In regard to problems of interpolation and extrapolation, by which Pirsson obtained such close agreement between calculated and observed chemical composition, we are not in a favorable position, since the analyses which I have made exhaust the known main types of abyssal rocks at the locality. A comparison of the analyses of the dike rocks given by Williams with the curves in Diagram 3 confirms the supposition expressed in my former paper that the tinguaites and the nephelite-porphyry are aschistic, and that the fourchites and ouachitites like the covite, are diaschistic.

It was expected that the analyses of the Fourche Mountain pulaskites would fall in with the curves as laid down. But, determining the abscissal position by silica, it is found that Al_2O_3, Na_2O, and K_2O are below, and (FeO), MgO and CaO are above, what would be their "normal" positions, as will be seen on reference to the diagram.

Although these rocks are unquestionably derived from the same general magma, yet, as their distance from Magnet Cove is about forty miles, it is clear that we need not be surprised to find discrepancies, due to differences in the process of differentiation.

---

[1] C. BARUS, *Am. Jour. Sci.*, Vol. XLIII, p. 56, 1892.

At Magnet Cove we have, without any doubt, the results of the differentiation in place of a small body of magma. This particular mass may have had originally the composition of the magma underlying the whole region, or it may have been itself a differentiate of this. Differentiation in such a large body of magma as that underlying the whole igneous region of Arkansas would naturally be likely to give rise to diverse products at different points, in which, however, could still be traced some of the original general characters of the whole. We are as yet scarcely in the position to deal with such intricate and obscure problems, but the results of Pirsson's investigations and of those embodied in the preceding pages seem to furnish a promising means of attack.

HENRY S. WASHINGTON.

PECULIAR EFFECTS DUE TO A LIGHTNING DISCHARGE ON LAKE CHAMPLAIN IN AUGUST 1900.

After a period of long continued drought, when the ground was very dry, a thunder shower arose in the Adirondacks, which passed east, crossing Lake Champlain over Westport and along south of the crest of Split Rock Mountain. No rain fell north of the top of the mountain, but a very severe storm passed to the south. When the storm had nearly disappeared, a sudden discharge of lightning passed down from the clouds, striking about half way down the northern slope of the mountain, entirely outside of the rain area and into the dry trees and rocks. In about a half a minute a cloud of what appeared to be dust could be seen rising from among the pines and juniper bushes. This, however, in a couple of minutes proved to be smoke, and in less than five minutes a very well developed forest fire was under way. Fortunately, a number of persons saw the discharge and saw the fire start, and immediately hastening to the spot were able to extinguish the fire before it had burned over more than a small fraction of an acre.

The peculiarity of the discharge was immediately observed upon coming upon the locality. An old pine tree seemed to have received the most severe part of the discharge and was badly split in the familiar manner. In addition to this, however, a number of places were immediately noticed where the lightning had struck either into the rocks or into the dirt overlying the rock. In two cases the discharge into the rock was of such force as to split the rock, tearing up fragments weighing as much as fifty to one hundred pounds and scattering them about. In other places the discharge upon the rock was comparatively slight, producing simply small fractures in the rock, and in some cases the effect was so slight as to simply remove the dry moss, leaving a small white spot not as large as the finger-nail. These partial discharges of such varying force were scattered over an area of perhaps thirty to forty feet square, the more violent ones being within twelve or fifteen feet of each other. Upon examining the point at which any one of these discharges struck, a white incrustation was apparent upon the rock, as if white paint had either been spattered about or had been spread over as a rough, branching, straggling line. These white incrustations, in some cases, could be traced for a foot or more down into the cracks between the rocks. In other cases, they were mere spots. These white streaks were, undoubtedly, the paths along which the electricity ran, and a superficial examination showed that the white was due to an incipient fusion of the surface of the rock. Unfortunately, it was not practicable to get satisfactory photographs of these markings or to bring in large specimens. Small specimens, however, were brought in, and have been subjected to investigation.

The probable explanation of the scattering discharge of this particular lightning is to be found in the extreme dryness of the ground. The cloud charged with electricity would, of course, induce the opposite kind in the trees and rocks immediately beneath it. Then, when the discharge came, it was necessary that each prominence should discharge to the cloud ***individually***, because the ground connecting the different prominences was too poor a conductor to rapidly collect the quantities of electricity and discharge them through a single point, as is usually the case.

WILLIAM HALLOCK.

COLUMBIA UNIVERSITY,
New York City.

A STUDY OF THE STRUCTURE OF FULGURITES.

Some obscure problems in structures occurring within artificial and natural glasses (rhyolites, tachylites, etc.) receive light from the study of fulgurites, as representatives of instantaneous fusion, and frequently, as it will be shown, of equally rapid devitrification.

Hitherto, however, a constitution of homogeneous glass has been universally observed, under the microscope, in all sand-fulgurites, without the least trace of devitrification in the largest masses.[1] Occasional cloudy stains of brown iron-oxide and black manganese-oxide have been noted, and frequent enclosure of remnants of quartz-grains[2] and of bubbles, both more abundant near the outer walls of fulgurite.[3] In rock-fulgurites, a single instance of devitrification has been recorded. The results of examination of four fulgurites will now be described.

I. *Fulgurite* (lightning-tube) from sand, *Poland;* a small fragment, together with thin cross-sections, prepared by Mr. James Walker, of the New York Microscopical Society. This fulgurite is of small size, from 5 to 8^{mm} in diameter, with central aperture or lumen usually 2.5 to 4^{mm} in diameter, and glass wall varying mostly from 0.6 to 2.0^{mm} in thickness, roughened outwardly by adhering sand-grains in a continuous coating. The photomicrographs (Figs. 1 and 2) may serve to explain certain features as yet unrecognized in other fulgurites.

The wall presents, under low magnifying power, an apparently homogeneous glass, streaked by occasional cloudy wisps of brownish and reddish iron-stains, and besprinkled with swarms of bubbles of varying size.

---

[1] "A Perfect Glass," Arago (*Ann. d. Ch. et. d. Phys.*, Vol. XIX (1821), p. 290) and all later investigators.

[2] Von Gümbel, *Zeits. d. D. geol. Ges.*, Vol. XXXIV (1882), pp. 647–648.

J. S. Diller, *Am. Jour. Sci.*, Vol. XXVIII (1884), pp. 252–258.

G. P. Merrill, *Proc. U. S. Nat. Mus.* (1886), p. 84.

[3] Best shown in the longitudinal and cross-sections of a sand-fulgurite by A. Wichmann (*Zeits. d. D. geol. Ges.*, Vol. XXXV (1883), Pl. XXVIII).

The inner surface of the lumen is for the most part smooth and shining, with boundary sharply defined in cross-section (Fig. 1), as in other fulgurites; but, here and there, a few points, pustules and needles of glass are found to project, of a length up to 0.17^{mm}. For the origin of the central lumen an explanation long accepted has been that suggested by Watt for the hollows in a fulgurite-mass, "the expansion of moisture while the fusion existed.[1] In this cross-section the outline is

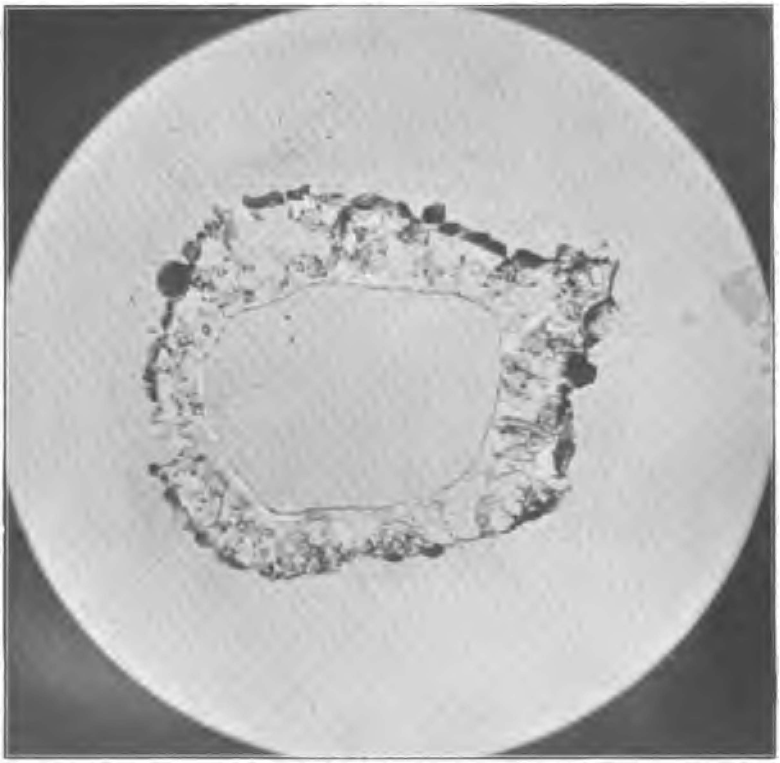


FIG. 1.—Sand-Fulgurite, Poland. × 10. Photomicrograph of cross-section.

---

[1] *Phil. Trans. Roy. Soc. Lond.*, Vol. LXXX (1790), p. 302.

nearly circular, with maximum and minimum axes as 4 : 3 ; in another it is still more elliptical. This difference, common in sand-fulgurites, has been attributed to distortion of the tube by pressure of the surrounding sand upon the fulgurite while still plastic. In one cross-section, one side of the tube appears partly crushed together, with coalescence of opposite parts of the wall into a blebby mass of coarse bubbles and partial obliteration of the lumen. The characteristics of such a fulgurite seem therefore to be naturally divided into those developed during the sudden dilatation of the tube, and those which may have ensued during its quick compression and in places partial collapse.

In regard to the distribution of the bubbles or vesicles, three vaguely marked bands may be distinguished :[1] a marginal tract, next the lumen, comparatively free from vesicles and clear: a middle portion of the wall comprising most of the larger vesicles; and the gathering of dark swarms of the more minute vesicles toward the outer margin.

The last (partly shown in Fig. 2) vastly predominate in number over the larger vesicles, are almost universally spherical, vary greatly in diameter down to 1μ or less, and compose the dark clouds, seen under low magnifying power, on inner side of sand-grains adhering to outer side of the wall. Others are also dispersed more irregularly in lines and bands through patches of the glass (best shown under magnifying power of at least 300 times). A careful search was made among these dark bubbles, particularly the most minute, by means of a tenth-inch objective of good definition, for traces of enclosed water, but no liquid could be distinguished. From this I conclude that any watery vapor, derived from moisture present in the sand, has been mostly expelled in the explosions, and also that this has probably had far less to do, in expansion of the lumen and formation and compression of bubbles, than the elastic force evolved by sudden heating of the large volume of air occupying the interstices of the sand-grains. The bubbles should therefore be more properly denominated air-vesicles (*luft-blasen*) than vapor- or steam-cavities (*dampf-poren.*)

---

[1] In a fulgurite from Milton, Florida, no definite order of arrangement occurred. (MERRILL, *loc. cit.*, p. 90).

The larger vesicles, which mostly occupy the middle part of the tube-wall, seem to have been produced by crowding together and coalescence of smaller ones. The largest, which have been perforated and emptied, in making the thin section, present light outlines, up to 0.2 to 0.3^{mm} in diameter, mostly elliptical, but also oval, pearshaped, lenticular, triangular, or squeezed together in groups, with contiguous walls flattened by pressure in direction tangential to the tube-wall. Even a particular vesicle may vary much in size and in form of cross-section at different depths, as if distorted after formation. The longer axes of the

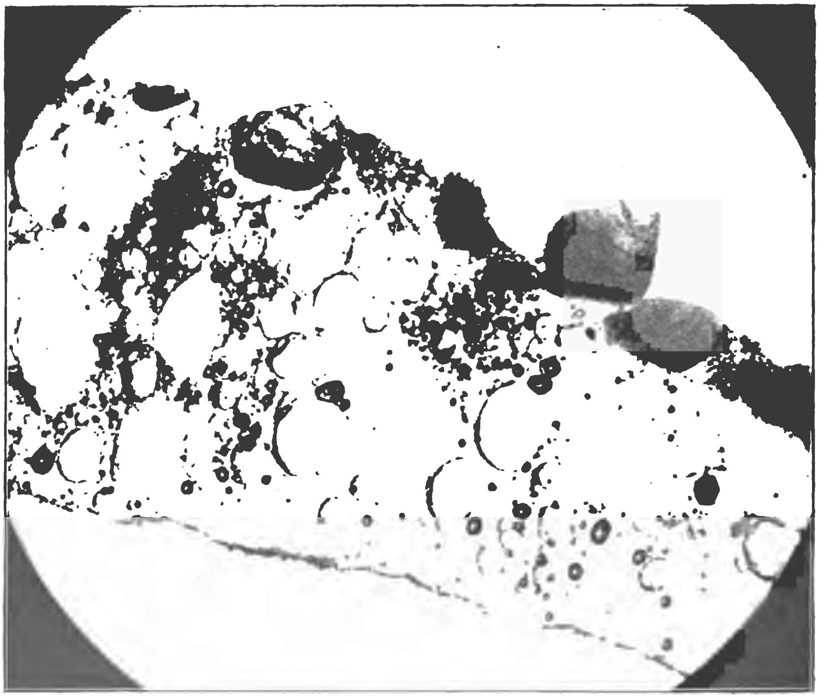


FIG. 2.— The same. × 50. Part of wall.

elongated vesicles are in general disposed radially[1] toward the lumen of the tube, though occasionally one may lie obliquely or even at right angles to that direction, as if twisted around by a sudden thrust. All the facts seem to point to strong lateral or tangential compression of the vesicles within the surrounding glass wall, and to their consequent extension and distortion in the direction of relief.[2]

The sudden expansion of air and vapor by the electric discharge has thus effected the dilatation of the lumen, the generation of bubbles throughout the fused glass, and the coalescence of those first formed into the larger vesicles. The relief of this tension outwardly, toward the margin of the tube, first caused the radial elongation of the larger vesicles and extension of conical projections and wings from outer side of the plastic tube, aided, doubtless, by lateral offshoots of the electric current.[3] Then, in the moments succeeding the passage of the main current, the effects of sudden condensation, lateral contraction and recoil are shown in the instances of partial collapse of the tube, in the reverted distortion of vesicles, *i. e.*, inwardly toward the lumen, and in explosion of some bubbles nearest the lumen into pustules and points of glass over its surface. Where the glass retained its plasticity longer, the vesicles have recovered their normal spherical form; this condition seems to have been regained in nearly all fulgurites whose vesicles have been carefully examined by others. It is to be noted that elongated vesicles in radial position have been recorded in only two cases of rock-fulgurites, in both within partially devitrified glass, as found in one by Rutley and in the other by Wichmann; in the latter case (viz., fulgurite III, beyond) I have made the same observation, in addition to fulgurites I, II, and IV. Their exclusive association, therefore, with devitrification may be a consequence of more sluggish movement and imperfect recovery from distortion within the more viscous crystallite-laden glass.

---

[1] A position already recognized in other fulgurites by Wichmann and Rutley.

[2] One writer considers "this radial arrangement . . . . possibly indicative of a rudimentary crystallization in the fulgurite glass" (RICHARDSON, *Min. Collector*, Vol. III (1896), p. 132).

[3] MERRILL, *loc. cit.*, 87. One consequence of these offshoots, and of the ozonized atmosphere thereby developed, is shown in the reddish stains, due to oxidation of iron, in the sand surrounding a fulgurite, to the distance of 3 or 4 inches; *e.g.*, in that found near Starczynow, Poland (ROEMER, *N. Jahrb. f. Min.*, 1876, pp. 33–40).

Another feature, quite distinct in the vesicles of larger size, is the separation of each from the surrounding glass by a limpid pellicle, never exceeding 0.2μ in thickness. This appears both in cross-section, with sharply differentiated outlines, and also in jagged remnants around the margin of an emptied vesicle, on surfaces of the thin section, like the edges of a broken eggshell. It may be considered a glass coating, suddenly chilled and condensed in contact with the bubble, at first consolidation of the tube-wall.

Around the outer margin of the wall occurs, as usual in sand-fulgurites, a continuous row of adhering sand-grains (Fig. 1), semi-fused and to that extent rendered white and opaque. These grains are partly rounded and from 0.2 to 0.6^{mm} across. All were successively examined around the thin cross-section by the usual optical methods, those of feldspar being generally recognizable by traces of cleavage, cloudy alteration, oblique extinction, lower interference-colors than those of quartz, and more or less complete biaxial interference-figures, whose negative character could often be distinguished. Out of 35 grains 23 were identified as orthoclase, the remainder as quartz. In the more angular grains wavy extinction testified to remaining mechanical stress. The indications are that the original sand was very fine and highly feldspathic, free from mica and with few ferruginous particles.

While the outer extremity of a sand-grain, so attached to the glass wall, often retains its translucency and color entirely uninjured by the electric discharge, this is sharply divided from an altered milk-white inner portion, in which the change consists mainly, with quartz, in very minute fracturing and consequent opacity. This passes, with feldspar, into a translucent border, next the glass, in which minute needles or crystallites abound, suggesting immediate devitrification after fusion. From this border very irregular milky threads descend into the glass in a confused network, swarming with the most minute air-bubbles, approaching 1 or 2μ in diameter. In this vicinity, also, fibrous threads or streaks of glass occur, which display, between crossed nicols, feeble colors of aggregate polarization.

On reception of this fulgurite from Mr. Walker, he stated: "I have noticed in several places on the outside of the tube . . . . some very fine threads of fused quartz, like delicate spider-webs, connecting the sand-grains, as if the partly fused grains had been forced apart while still soft." This new feature in fulgurites I can confirm. The glass threads are colorless, brownish, or sometimes black; generally smooth and glistening, but occasionally roughened; more or less curved; passing from grain to grain of the adhering sand, but sometimes projecting as if broken; mostly 0.4 to 1.1^{mm} in length, and 0.015 to 0.04^{mm} in width.[1] In the glass between neighboring sand-grains many minute round holes are also perceptible[2] under a low magnifying power, apparently produced by exploded bubbles. In several cases, in the glass behind a sand-grain, there is a limpid band with faintly marked outline (best shown in photomicrograph, Fig. 2), the latter corresponding to the back contour of the sand-grain. This must mark its original position before it was jerked outward to a distance of half its diameter and the space behind filled in at once with clear glass, distinct because free from bubbles. To the force and extent of this outward jerk, in some instances, the glass threads doubtless owe their formation.

Between crossed nicols the thin section at first appears dark, like a homogeneous glass, with the exception of the ring of highly refracting sand-grains outside and occasional gleams of reflection from scattered air-vesicles. In ordinary light, under low magnifying power, a faint granulation is discernible throughout the glass. This is resolved under higher power (× 300) into an irregular, sparse to abundant distribution of crystallites through a predominant glassy base, from the margin of the lumen to the fusion-border of the sand-grains. No special concentration occurs, except in occasional richer wisps and streaks, like diffusion-streams, across minute patches of clearer glass. In general they are scattered in the same way among and near to the air-vesicles. In some cases, however, an elongated vesicle is surrounded by a band of perfectly clear glass, free from microlites, 5 to 10μ in width, which broadens to 20 or 30μ opposite the ends of the major axis of the vesicle. This has been plainly due to compression and extension of an original envelope of viscid glass, chilled and consolidated by proximity of the vesicle, before devitrification could take place within this envelope. But in general throughout the glass we may recognize one condition that has favored crystallization, in the influence of absorbed vapors, through the abundantly intermixed bubbles.[1]

---

[1] A coating of sublimed silica is often found upon the carborundum crystals manufactured in the electric furnace at Niagara Falls. The interlaced threads of quartz of which it is composed much exceed the dimensions of the natural threads above described. They differ also in the variation of diameter in a thread and in the common occurrence of a peculiar beading along many threads.

[2] MERRILL, *loc. cit.*, p. 84.

These microlites are straight or curved, sometimes lath-shaped, less than 1μ in length in some cloudy aggregates, but largely 3 to 13μ, or even extend into threads, often bent or crooked, 30 or 40μ in length. They lie in all positions and never display any fluidal arrangement,[2] though the larger number seem to be radially disposed toward the center of the fulgurite-tube. Between crossed nicols the microlites exhibit very feeble double refraction, mostly pale gray, here and there brightening into pale greenish-white of the first order. All these forms appear to represent the regeneration of feldspar. A very few margarites were also distinguished, and one spherulite of about 3 μ diameter, made up of concentric shells, which exhibited a faint cross, remaining fixed on rotation.

---

[1] As in the pumiceous glass of the fulgurite of Little Ararat III, as well as in the devitrified glass of Monte Viso, of which Rutley states that the vesicles are sometimes so closely packed that the glass is quite spongy. However, the pumiceous glass of other fulgurites has been found entirely homogeneous.

[2] In fulgurite-lumps from Florida, Merrill recognized a fluidal structure in the homogeneous glass near bubbles, "as if by sudden expansion of a steam-bubble in the plastic material" (*loc. cit.*, p. 87).

This unique occurrence of devitrification in the glass of a sand-fulgurite is perhaps mainly connected with the high proportion of feldspar in the original sand. Such a chemical constitution must have approached that of the rhyolite[1] used in the experiments of Barus and Iddings, whose viscosity and whose electric conduction, when fused, were both found to exceed those of the less acid rocks, and led to the conclusion that "electric conduction increases with the degree of the acidity of the magma. . . . . Since fusibility decreases in a marked way as the composition of the magma approaches pure silica, it follows that, in a series of different magmas, electric conduction at any given temperature increases in proportion as the viscosity increases." From this it must be inferred that the more quartzose sands, when once melted by a lightning stroke, have offered the viscous medium of readiest passage to the current.

Exception has been rightly taken, however, to the assumption that the material of a fulgurite-tube was necessarily or entirely "quartz-glass."[2] The general distribution of feldspar in notable quantity through ordinary sands is a fact in favor of the suggestion of Wichmann and Harting, that the minerals of comparatively ready fusibility have served as flux and thus ended in reducing the more refractory. Particularly then in this fulgurite do we need to consider not only the relative fusibilities of feldspar and quartz, but also the relative degrees of their solvency in contact with the first formed portion of molten glass, doubtless so instantaneous in formation as to be independent of all differences in fusibility, solution, conduction or any other property of the various sand-grains.

To throw light on this question and on the variations, recorded beyond, in devitrification of such natural glasses, a preliminary examination was made of a specimen of artificially vitrified gneiss, with brown glassy fracture, obtained from the hearth of a limekiln at Tuckahoe, N. Y. This had been evidently thoroughly roasted and deprived of moisture but not fused (as the gneiss structure still perfectly survived, in the undisturbed parallel biotite-scales), saturated with slag from the kiln, and finally thrown out and slowly cooled upon the refuse-dump. In a thin section under the microscope, the results of the action of fused glass upon the original minerals of the gneiss were found to be as follows: a slight solvent attack upon the biotite, rendering it in part opaque, with brown haloes and cloudy wisps of iron oxide feathering out into the adjacent glass, apparently by quiet molecular diffusion; a decided but partial solution of the quartz, of which a small portion survived in angular remnants, still in place; and complete solution and disappearance of the feldspar. The main mass of the saturated rock had thus been converted into pure colorless glass, with a few coffee-colored stains, without any trace of crystallites or new stony matter, notwithstanding its slow cooling. However, globules of clear glass, about 0.5^{mm} in diameter, were abundantly interspersed, colorless like their matrix and with little adherence, since many had become loosened and removed from the surface of the thin section during the process of grinding. It was consequently inferred:

---

[1] Silica, 75.5 per cent.; alumna, 13.25; soda, 4.76; potassa, 2.85, etc. Heated in a platinum crucible, it melted at 1500° C., was very viscous ("a stiff paste") even at 1600°, and quite viscid at 1700°. *Am. Jour. Sci.*, Vol. XLIV (1892), pp. 242–249.

[2] See v. GÜMBEL, *loc. cit.*, and *idem.* Vol. XXXVI (1884), pp. 179–180, and criticism by A. WICHMANN.

1. That minerals of acidic constitution, feldspar and quartz, may be largely carried into solution, in contact with fused glass, at a temperature below their thermal melting points.

2. That their fused products tend to cohere *in situ* in spheroidal globules, through possession of a different degree of density, viscosity and contraction on cooling, from that of the surrounding glass.

3. That the process of devitrification has been prevented in this vitrified gneiss by the peculiar constitution, probably the acidity, of the unsaturated glass, and by an insufficient period of cooling.

In the development of a sand-fulgurite by almost instantaneous fusion, it is unlikely that any selective power could have been exerted among the sand-grains, through their slight variations in fusibility, conductivity or other property. All within a radius of a few millimeters were suddenly and completely fused, with a limitation so sharply defined, in this fulgurite, that, in any sand-grain, the quartz or feldspar may remain entirely unaltered within an interval of about 0.02^{mm} of the same material fused and again devitrified. The molten mass of its wall became a supersaturated solution of feldspar, with specially strong solvency, however, toward any external quartz-grains within its reach, through the tendency to form more acid silicate. Such action probably accounts for the increased amount of silica which has been determined in fulgurite-glass over that in the original sand in several instances.[1] In this fulgurite also the preponderance of feldspar over quartz in the attached sand-grains may possibly have become exaggerated by the slower solution of the former mineral.

The view has been advanced[2] that a selective power of fusion has been exerted by the electric current among the grains, but without regard to their fusibility: the poorer conductors (quartz-grains), offering so strong resistance as to become heated to the point of fusion, those substances which are the best conductors (iron-oxides and feldspars) escaping with least injury. It is notable, however, that it is not a good conductor but quartz only which has ever been recognized in remnants of grains inclosed in the glass of other sand-fulgurites, and that no remnants whatever are enclosed within the glass of this fulgurite, apparently because so rich in flux.

Three rock-fulgurites will now be described in the order of increasing devitrification.

---

[1] In a fulgurite from Union Grove, Ill., silica 91.66 per cent. in the glass to 84.83 in the sand; in another, 95.91 in the glass, to about 90 in the sand. (MERRILL, *loc. cit.*, p. 85.)

[2] MERRILL, *loc. cit.*, p. 87. Diller notes, however, in a fulgurite on hypersthene-basalt, that the sequence of alteration is according to degree of fusibility of the components of the rock, greatest in the groundmass, then hypersthene, then feldspar, and least in olivine.

II. *Fulgurite* on gneiss, near *Split Rock, Lake Champlain, New York;* specimen collected by Professor William Hallock, of Columbia University, immediately after the lightning-stroke, as described in his accompanying article. Thin sections of this granite-gneiss were prepared, one in plane parallel to and within about 0.03^{mm} of the fulguritic crust, the other in cross-section. The rock is found to present a surface somewhat dulled by weathering, and to consist, to about 70 per cent. of its volume, of feldspars, microcline, microperthitic orthoclase and a little plagioclase, besides much quartz and a small amount of magnetite, biotite, garnet, and rutile, but no trace of fulguritic glass. No undulatory extinction occurs between the nicols, as evidence of strain.

The fulgurite-pellicle is entirely superficial,[1] brittle, and with slight adherence to the rock, from 0.1 to 0.3^{mm} in thickness, nearly white, consisting chiefly of a minutely blebby hyaline crust with blistered, glistening surface, whose bubbles, rarely exceeding 0.2^{mm} in diameter, are nearly spherical but somewhat elongated normally to the surface of the rock. On careful examination of these, in a flake mounted in balsam, under a good tenth-inch immersion objective, no water of condensation could be detected in any vesicle.

Many short glass-fibers occur, sometimes with globular ends, resembling some of those in "Pele's Hair" from the crater of Kilauea, Hawaii. This white pumiceous slag is quite uniformly attached to the predominant surfaces of feldspar, though pierced by the uncovered gray grains of quartz. It is dispersed over the rather even surface of the hard gneiss in radial, somewhat dendritic forms, often many inches in length, thinning out into feathery fleeces at the margins. Wherever these pass over minute plates and seams of the dark minerals of the rock, the blebby fulgurite assume a yellow, red, brown, or black color, as a dark enamel, or in the form of tiny spherules.[2]

---

[1] Similar superficial films of fulgurite have been often observed, by Humboldt in Mexico, by Brun in the Alps, by Ramond on mica-schist, on limestone, and on phonolite in the Pyrenees and Auvergne.

[2] Over the fulgurite-crust on hornblende-gneiss at Mount Blanc distinct white and

The white material, when flaked off and mounted in Canada balsam, reveals a limpid glass, dispersed with very few and minute straight microlites and very rarely rhombic plates; the latter display rather bright interference-colors between crossed nicols and parallel extinction.[1] Where thinnest, the glass remains isotrope and dark, while the thicker portion, generally toward the center of the flake, glows with the greenish-white of the first order of Newton's colors; in places the color reaches the sky-blue of the second order, exactly like a thin scale of the underlying feldspar. The indications are that devitrification had begun, throughout the glass, in globulites too extremely minute for distinction, even under high magnifying power, but whose concentrated effect in depolarization becomes visible, between the crossed nicols, in the thicker parts of the flakes. The flakes of brown or colored glass, however, are found to be uniformly isotrope. It should be noted that, as the greater thickness of these flakes approaches or exceeds 0.5^{mm}, it is probable that the presence of crystallites might hardly have been recognized in a ground section of the ordinary thinness, 0.02 to 0.05^{mm}. In such an investigation plane surfaces are not indispensable, and the examination of splinters of a glass may serve an important office. Evidences of incipient devitrification, in fulgurites and other glasses, have possibly escaped detection by observers relying entirely on examination of thin sections.

The facts above described lead to the following conclusions:

1. We have here to do with different conditions from those

---

dark globules were dispersed: "the fused surface of each crystal solidified almost exactly *in situ*, except where sputtering of the molten matter was caused" (RUTLEY, *Quar. Jour. Geol. Soc.* (1885), pp. 152–156). The inclosed globules in the slag-saturated gneiss of Tuckahoe may represent a similar tendency to isolation.

[1] The homogeneity of glass which apparently prevailed in all fulgurites examined by the early observers led naturally to the statement in 1884 that the absence of crystallites "may be used as a means of distinguishing fulgurite from other natural glasses" (J. S. DILLER, *Am. Jour. Sci.*, Vol. XXVIII (1884), pp. 252–258). In 1889, Rutley made the first and hitherto the only record of the occurrence of devitrificatoin in a vesicular fulgurite-glass on glaucophane-schist, at Monte Viso, Cottian Alps. The crystalline forms consisted of globulites, margarites, and longulites, and even symmetrical microliths (*Quar. Jour. Geol. Soc.*, Vol. XLV (1889), pp. 60–66).

which attended the sand-fulgurite I, viz., the lessening force of a divided electric current, passing over the surface of a compact rock-mass. The effect of the electric action on this solid surface of gneiss has been more diffuse, feeble, and superficial than in the sand-fulgurite, and, in this case, confined to the feldspar.

2. The fulgurite crust has been produced almost entirely by fusion of surfaces of feldspar-grains rather than of quartz, and in small degree by that of the iron-containing minerals. The property of fusibility, rather than that of imperfect conduction, has determined the amount of attack on each grain. Each kind of glass, colorless and colored, is sharply confined to the mineral surfaces from whose fusion it originated, with little tendency to intermixture.

3. The bubbles throughout the fulgurite-crust owe their formation chiefly to expansion of air, and in part doubtless of steam, derived from moisture in the weathered surface of the rock. Their sputtering explosion has probably produced the tiny fibers over the blebby surface.

4. The surprising partial devitrification, which has instantaneously followed fusion throughout the delicate white pellicle, has been evidently facilitated by the supersaturated feldspar solution of which the molten glass almost entirely consisted, and by its consequent unstable molecular condition.

III. *Fulgurite* in augite-andesite, summit of *Lesser Ararat, Armenia.* The specimen was one of those collected by Dr. E. O. Hovey, of the American Museum of Natural History, New York.

The fulgurite material from this peak has received repeated study in the field or laboratory by successive observers. Abich[1] detected only pure glass in the fulgurite, but in such abundance that he suggested the name "fulgurite-andesite" for the material on the apex of the peak. Gustav Rose[2] also came to the same conclusion, and determined the difficult fusibility of the

[1] *Sitz. Akad. Wiss. Wien*, Vol. LX (1870), I. Abth., pp. 153–161.

[2] *Zeit. d. D. geol. Ges.*, Vol. XXV (1873), pp. 112, 113.

glass on thin edges. A. Wichmann[1] made the most careful petrographic study of this and other fulgurites and distinguished this as "entirely homogeneous glass," without any alteration of the andesite at the sharply defined contact. He considered the bubbles as vapor-cavities (*dampf-poren*), and gave a clear representation of the structure of a lightning-tube in a well-drawn cross-section. The results of my own examination, which follow, differ in some important particulars.

The augite-andesite of this peak, though consisting of fresh plagioclase-feldspar, with some partly decayed augite, hornblende, orthoclase, and magnetite, is deeply disintegrated by weathering, so that, in some blocks, its grains crumble readily under pressure from one's fingers. It is also traversed, even in the most solid material, by numerous cavities and channels, a few millimeters in width, of most irregular form, crossing and connecting with each other at intervals of a few centimeters. Most of these passages, in the more decayed specimens I have examined, in the collection of Dr. Hovey, are one or two centimeters in width, and often coated by the olive-green fulgurite glass to a depth of 1 to 1.5^{mm}; some are even solidly filled up by the glass, with a cross-section of 5 to 8^{mm} in diameter or over. Other cavities of exactly the same form and size were noticed, adjoining but not connecting, which are now and appear always to have been entirely free from fulgurite. Most, if not all of these, therefore, seem to be preëxisting cavities, later occupied in many cases by fulgurite. A confirmation of this is found, by optical examination of the thin sections, in the absence of undulatory extinction in the grains of minerals adjacent to the fulgurite, *i. e.*, the lack of any indication of strain likely to have resulted from actual perforation of the rock by lightning. On the other hand, certain other specimens in the collection from the same peak are penetrated by cylindrical winding tubes,[2] lined or filled with the dark glass, which seem clearly to owe their perforation to the action of electric discharges upon more disintegrated blocks of the crumbling rock.

---

[1] *Idem.*, Vol. XXXV (1883), pp. 849–859.

[2] The approximately cylindrical form of the latter, and their curved windings, have been well represented by Rutley, from the fulgurite furrows on glaucophane-schist at Monte Viso, Cottian Alps (*loc. cit.*, plate).

The glass is found to be rich in bubbles, especially toward and near the surface of the inner rock-wall, and in places even blown up into blebs and blisters. All of the smaller vesicles and most of the larger are approximately spherical. In none of these could any water of condensation be discovered under a tenth-inch objective; their contents appear to be entirely gaseous, *i. e.*, chiefly derived, in all probability, from expansion of air rather than steam. Many of the larger vesicles present a more or less elongated form, with major axis always arranged in position at right angles to the adjacent rock-wall. This distortion of vesicles in the glass of a rock-fulgurite may be always attributed, in my opinion, entirely to the reaction of pressure inward, *i. e.*, toward the lumen, which has instantaneously followed the passage of the electric discharge, mainly from expansion of the collected bubbles, partly from increased volume of the glass during fusion of the rock.

When crushed splinters of the glass are examined, though found sometimes entirely amorphous, as reported by Wichmann and others, it is also in places rich in bunches of stony matter, isolated needles (with bright interference-colors between crossed nicols and parallel extinction) and clusters of microlitic fibers, sometimes radiating around a bubble.

Again, at the line of contact between this glass and the andesite-wall, an intermediate stony layer occurs, 0.15 to 0.70^{mm} in thickness, containing a few obscure outlines of bubbles. This plainly consists of wholly devitrified glass, made up of a felt of irregularly crossing needles, fibrous curved wisps, or straight bundles, some rectangular in form, 0.08 to 0.20^{mm} in length, whose axes lie mostly parallel to the line of contact with the adjacent rock-wall. In the straight bundles an extinction-angle of about 19° is uniformly obtained, often with undulatory phase, and all offer the characteristics of orthoclase. There is a remarkable resemblance, if not identity, of these fibrous aggregates, in form, structure, and optical character, to the artificial microlitic bundles obtained in the experiments of J. S. Diller (*loc. cit.*) by long fusion of amorphous fulgurite-glass in crucibles.

The difference of the above results from those hitherto reported from study of the fulgurite of this peak may be attributable to variation in the structure of the fulgurite, particularly in regard to devitrification, in different parts of the surface.

IV. *Fulgurite* from summit of *Central Butte*, *Little Missouri Buttes*, *Wyoming;* specimen collected by Mr. John D. Irving. This is a small fragment of phonolite, apparently from the edge of intersection between two joints, down which corner the fulgurite runs in a shining, cream-colored, slightly brownish crust, about 15^{mm} wide and 3^{mm} thick. On a fractured cross-section it shows distinct lamination parallel to the surface of contact, as if the latent structure had been developed by weathering.

The rock consists mainly of orthoclase-phenocrysts, whose idiomorphic character is obscured by fractures, imbedded in a smaller volume of granular, somewhat ochreous holocrystalline groundmass, through which needles of hornblende, plagioclase, apatite, and granules of magnetite are dispersed. Between the crossed nicols, the transparent minerals, in a thin section, generally display a decided undulatory extinction, in evidence of condition of strain.

This fulgurite exhibits under the microscope the unique character of a wholly devitrified mass, light brownish-gray, delicately laminated in cross-section (*a*, Fig. 3) by a very irregular flow-structure,[1] with interruptions and intersections of laminæ suggesting those observed in the cross-stratification of certain sand deposits. Some laminæ, especially near the contact-line (*e. g.*, just below *c'*), are bent and faulted, with ends slipped past each other. The thicker laminæ consist of very minute, colorless needles, fibers, and granules, in an irregular felted mass, through which obscure circular and elliptical outlines (*b*, etc.) indicate the position of numerous original bubbles, now flattened, freed from gas, and even partly obliterated. With this darker material, evidently entirely devitrified glass, there occur frequent alternations (*d*, *d*, etc.) of thin films of a microscopic breccia or "mylonite," shining brightly between the crossed nicols. This is composed apparently of rock-dust,[1] made up chiefly of angular splinters of feldspar; a few coarser fragments of the same are also irregularly interspersed (*f*). Along the line of contact (*d'*), the same angular dust is drawn out in streaks or gathered

---

[1] Compare the thin underlying coat, in which fusion is less complete, with dark fluidal banding, and which envelops numerous crystal remnants, described by Diller in the "mixed zone" of fulgurite-glass in immediate contact with basalt at Mt. Thielson (*loc. cit.*). Of this he states, it is difficult to conceive how it has been produced, "unless it is due to the repulsion of the particles among themselves."

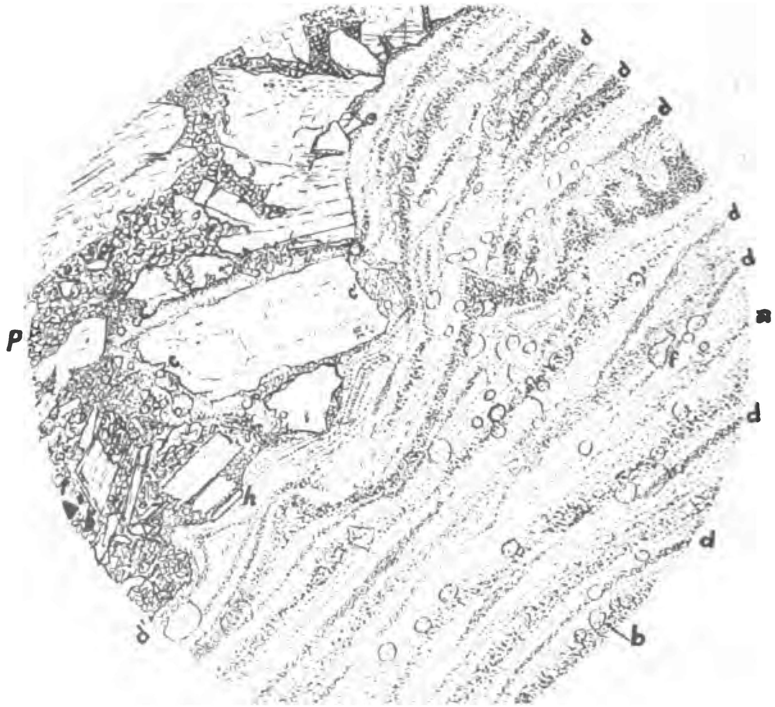


FIG. 3.— Rock-Fulgurite, Wyoming. × 50. Cross-section of contact.

---

[1] Apparently related to the opaque whitish layer, between the glass and rock, in the fulgurite of Monte Viso, and referred by Rutley to altered titanite.

in embayments. Its origin is well shown next the Carlsbad-twin of orthoclase (*c–c′*), whose outer end (*c′*), projecting into the fulgurite current, has been shattered into this dust to a depth of 0.1^{mm}, seemingly after the adjoining fulgurite laminæ had somewhat consolidated. This and other feldspar-grains lying along the edge of the stream, have been completely encircled by fulgurite, with an inner film of angular dust, marking the outline of the minutely shattered surface of feldspar. This micro-breccia is brought out between the crossed nicols in distinct bright stripes. The phonolite groundmass generally shows rather deeper embayments by fulgurite-attack than the feldspar-grains; but the hornblende-needles seem to lie entirely unaffected, even in immediate contact (*h*) with the fulgurite-stream.

It is possible that the devitrified crust which constitutes this fulgurite may be a remnant of an inner stony layer (as in Fulgurite III), from which a glass-coating may have been scaled off during weathering; but of the latter there is no evidence, and the stony crust now occurs coated by small lichens. Yet the peculiar structure of this crust, with its alternations of micro-crystalline and of micro-brecciated laminæ, signifies that devitrification has not been a secondary process due to weathering of a glass.

RÉSUMÉ.

Considerable variation appears, in the characteristics of these rock-fulgurites, from two probable causes: the variations in the electric current, in regard to volume, intensity, duration, and a probable series of successive discharges, in some cases, within the same fulgurite (IV); and the difference of the rock-material in the three specimens, gneiss, andesite, and phonolite.

In regard to the duration of a lightning-flash, it is understood not to have usually exceeded one hundred thousandth of a second (Sylvanus Thompson). The discharge is known to be oscillatory, surging back and forth, and even in many cases, like that observed by Professor Hallock, apparently persistent and continuous for some moments. Nevertheless, allowing for the

PHYSIOGRAPHY OF THE BOSTON MOUNTAINS, ARKANSAS[1]

THE highlands of Arkansas lie in the northwestern part of the state, and comprise about half its area. They are divided, physiographically, into a north and a south part by the valley of the Arkansas River. They are also divided structurally into the same parts, the former being a region of horizontally-bedded rocks, somewhat disturbed by faulting and folding, while the latter, known as the Ouachita Mountains, is distinctly a folded region.

This northern division of the Arkansas highlands, with its westward extension into Indian Territory, constitutes the southern part of the Ozark region.[2] In Arkansas, it is divided into a low and a high part, the former extending northward into Missouri, and passing, along its southern border, into the latter, by an irregular but bold escarpment from 500 to 1000 feet high.

It is this latter region that is known in Arkansas as the Boston Mountains. Including that part which lies in Indian Territory, its total length is about 215 miles, about 170 of which is in Arkansas. Its average width approximates 35 miles. On the south, it passes into the valley of the Arkansas River by steep slopes, though less precipitous than those on the north.

These mountains are by far the highest part of the Ozark region as well as the most picturesque. Their highest point, so far as determined, is some miles east of the town of Winslow, on the St. Louis and San Francisco railway, where the altitude is 2,250 feet.[3] From this region of highest elevation, they

---

[1] Read before Section E of the American Association for the Advancement of Science at the Denver meeting, August 1901.

[2] The Ouachita Mountains have been included by some writers with the Ozarks; but because of the great structural and topographic differences in the two regions, to say nothing of the probable historic differences, this is manifestly wrong.

[3] Topographic map United States Geological Survey, Winslow quadrangle.

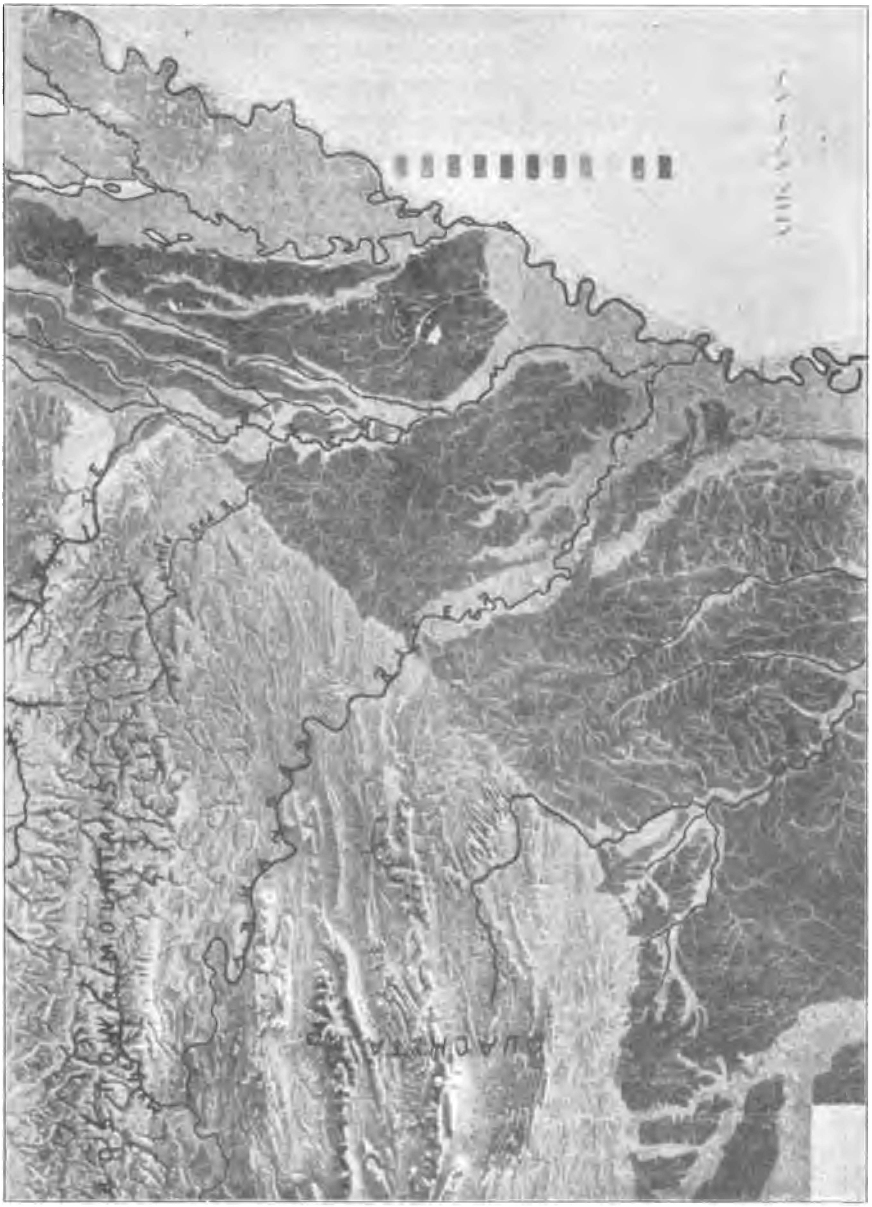


FIG. 1.—Photo from Branner's relief map of Arkansas.

gradually fall off to the east, sinking below the Tertiary deposits just west of the St. Louis, Iron Mountain and Southern railway and south of White River; also from this region of highest elevation, they fall off westward to the Grand River in Indian Territory.[1] It will be seen that the east-west line along the crest of these mountains forms a gentle arch in the middle. Structurally, in the western part of Arkansas, these mountains are a broad, flat anticline, the strike of which is east and west. According to the geologists of the Arkansas Geological Survey, it appears that the extreme eastern part of the region is monoclinal in structure, with the dip to the south.[2]

With the exception of the Illinois River in the western part of the state, the drainage of the region is northward and eastward into White River, and southward into the Arkansas. The direction of the streams has been determined by the slopes incident to the uplift, modified in some cases by faulting and flexuring. The effect of the latter upon Little Red River and neighboring streams has already been noted by Professors Newsom and Branner.[3] The westward course of the Mulberry River has been determined by a fault. Detailed work of the region would doubtless disclose numerous other similar examples.

The drainage of the region is that intermediate between youth and maturity. The streams are vigorous, and have completely dissected the plateau by the formation of gorges from 500 to 1000 feet deep, thus producing a very rugged topography over the whole region. Between these gorges the slopes often meet, forming more or less rounded hills; but more frequently the intervening area is occupied by flat-topped, sandstone-capped hills of limited extent.

The tributaries of both the Arkansas and the White rivers have worked their way back to, and in many cases, far beyond the original water divide of the plateau, making the water divide as it now exists, a very zigzag line. In the western part of the state, the south-flowing streams are the stronger, and as a rule are robbing the White River basin of territory in this locality. Further east, in the middle portion of the region, the north-flowing streams are the stronger, and seem to be encroaching upon the drainage area of the Arkansas, while in the eastern part, the south-flowing streams head very near the north escarpment of the plateau.

---

[1] DR. N. F. DRAKE, in *Proc. of the Am. Phil. Soc.*, Vol. XXXVI, No. 156, p. 332.

[2] NEWSOM and BRANNER, "The Red River and Clinton monoclines, Arkansas," *Am. Geologist*, Vol. XX, July 1897, pp. 1–13.

R. A. F. PENROSE, JR., *Ark. Geolog. Surv.*, Vol. I, 1890; section with pocket map.

[3] *Loc. cit.*

The rocks of the region are mainly unmetamorphosed sandstones and shales, those at the base being of Lower Carboniferous age, and those at the top belonging to the Coal-measure series. These alternating hard and soft rocks have produced the terraces on the hill slopes, which are so characteristic of dissected regions of horizontal strata. As these terraces are often of considerable width, and are favorable horizons for springs, they are inviting to the farmer, and can be located miles away by the small farms on the mountain sides.

The low region to the north of the Boston Mountains is one of great denudation. From its northeastern part, all the rocks have been removed above the Ordovician, leaving those exposed at the surface. West and south of this is a region from which the Upper Carboniferous rocks have been removed, leaving those of Lower Carboniferous age at the surface. Standing up prominently on the latter are numerous hills of circumdenudation, composed of remnants of the horizontal strata of the Boston Mountains, and serving as living witnesses to their former extent. The height of these outliers very closely approximates that of the plateau of which they were formerly a part. This uniformity in height between the various parts of the dissected Boston plateau and its outliers suggests a peneplain, and herein lies the physiographic problem of the region.

In a region of folded or inclined strata the determination of a peneplain becomes a question of comparative ease, for in those cases denudation will have reduced both hard and soft strata to practically the same level, the peneplain intersecting strata of all degrees of hardness. But in the case of horizontal strata undergoing base-leveling, the conditions are quite different, for then the peneplain conforms to the hard stratum or strata that happen to be near sea level. If such a region be subsequently elevated, the streams are revived, the region dissected, and the former peneplain represented by the tops of the hills, which would still be capped by the hard strata that were conformable with the peneplain before the region was elevated. Now this is exactly the structural and topographic conditions of the Boston Mountains and their outliers. But it happens that these are also the structural and topographic conditions that would prevail in a region of horizontal strata that has been elevated from beneath the ocean and is undergoing the process of base-leveling for the first time. So the problem presents itself as to which condition prevails in the Boston Mountains, and unfortunately criteria for its solution are largely if not wholly wanting.

Ordinarily, for the determination of a peneplain we look to the streams. In such cases, as is well known, the streams are winding, and flow in more or less steep-sided, symmetrical valleys, which are themselves cut down in wider valleys. In the Boston Mountains there is no such evidence of a peneplain. The streams of the region are all young, with the characteristic steep-sided gorges of such streams. So far as the writer has been able to observe, there is nothing in the region indicating an uplift since the present streams came into existence. Their valleys are relatively wide at their mouths, and gradually decrease in width back to their sources, as would be expected of streams cutting into a plateau of horizontal strata. The slopes are undisturbed by terraces, excepting such as those mentioned above, which are due to structure. Along the southern base, the oldest of the streams have reached the temporary base-level of the Arkansas River, and meander somewhat, but none of them to any great extent.

It follows that evidence of a former base-leveling, if there be such, must be looked for elsewhere than in the streams. A recent writer[1] claims that the tops of the Boston Mountains represent a peneplain, and cites as evidence the fact that they correspond very closely in height with the Ouachita Mountains south of the Arkansas valley. This evidence is given on the assumption that the rather uniform height of these mountains represents a peneplain; but this is a hypothesis far from being established. Mr. L. S. Griswold, in his work on the novaculite region of Arkansas, encountered the problem of the nonconformance of some of the main streams of the region to the structure and topography, to account for which he presents the theory of a post-Carboniferous base-level, on which was subsequently deposited Cretaceous strata.[2] If the present writer correctly interprets Mr. Griswold, he believes the south-flowing streams, which form water-gaps in some of the highest mountains of the region, are superimposed streams, their courses having been determined by the slope of the Cretaceous area after elevation. Mr. Griswold does not claim that the evidence of this is conclusive. It is the opinion of the present writer, from somewhat limited observation, that the even crests of the Ouachita Mountains are due to structural and lithological conditions and not to base-leveling. But were it established that they represent a peneplain, the fact that the Boston Mountains closely agree with them in height does not argue a peneplain for the latter. The one is a folded area, and the other an area of horizontal rocks (Fig. 2). Erosion in the one has resulted in wide, anticlinal valleys through which flow sluggish streams, while erosion in the other is in its early stages. It would seem to follow that the time of elevation of the one region is far antecedent to that of the other, and consequently the correspondence in height between the two only accidental.

If, however, we look to the north of the Boston Mountains, we find conditions which seem to throw some light upon the subject. As has already been said, this is a region of great denudation. Its general elevation is from 700 to 1000 feet

---

[1] O. H. HERSHEY, *Am. Geologist*, Vol. XXVII, No. 1, pp. 25 *et seq.*

[2] *Ark. Geol. Surv.*, 1890, Vol. III, pp. 220.

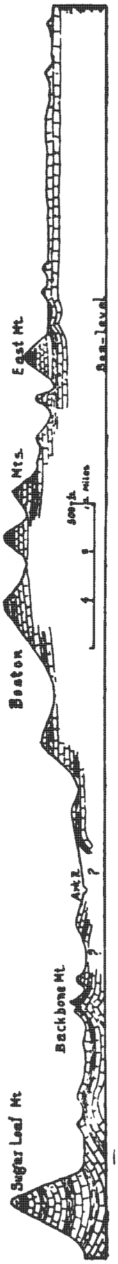


FIG. 2—North-south section of the Boston Mountains and adjacent regions, near Arkansas-Indian Territory line.

lower than that of the Boston Mountains. Its streams are mature, the valleys comparatively wide, and the topography in general presents the aspect of much greater age than that of the Boston Mountains. Professor C. F. Marbut, in discussing that part of this region which lies in Missouri,[1] claims that it was base-leveled in early Tertiary times, and the present cycle of erosion was instituted by an elevation which dates from middle or late Tertiary times. Be that as it may, the question as to whether the region to the north of the Boston Mountains ever suffered denudation to the extent of base-leveling does not particularly concern us here. The fact of interest is that the denudation of the extensive region to the north has been very great and the topography is old, while that of the Boston Mountains is limited and the topography young.

It would appear that this difference in topography cannot be attributed to the massive beds of sandstone at the top of the Boston Mountains, for these same beds, while they have doubtless had a great deal to do with preserving the region, formerly extended over much if not all the denudated area to the north. Besides, if we attribute the preservation of these mountains to the character of the rocks composing them, we are encountered by the question as to why erosion has been so extensive to the north of the region, removing the rocks over a large area, leaving only here and there hills or circumdenudation, while in the southern part adjacent to the Arkansas valley it has scarcely begun.

I am able to account for the great difference in the stages of erosion in the two regions only by conceiving the Boston Mountain area to have been at a lower elevation than the area to the north during the time the extensive denudation was going on over the latter. So low must it have stood that the strata now composing their summits suffered but little erosion, while the same beds extending northward suffered much because of their greater height. If this be true, the actual amount of degradation suffered by the Boston Mountain region is indeterminable; but as there was more or less of it, and the region stood at a low level, it would be considered a peneplain. The elevation, which must have occurred in late Tertiary or in post-Tertiary time, was greatest along the present east-west axis of the plateau, gradually decreasing to the northward, and changing the region from a low, monotonous plain to a plateau approximating 2,500 feet in height, greatly modifying the former drainage and instituting that of the present.

---

[1] *Mo. Geol. Surv.*, Vol. X, pp. 27–29.

Aside from the difference in topography between the region under discussion and the one to the north, the writer cannot at present claim very great support for the idea herein presented. There are, however, some other facts that seem to lend the hypothesis support. (1) The region being on the border of the Ozark uplift, it is probable that during the greater part of its history it lay at a low level and consequently suffered comparatively little from erosion. (2) The outliers of the Boston Mountains to the north are as a rule lower than the main plateau, though capped by the same rocks, thus indicating an axis of elevation to the south of the outliers. (3) The eastward course of White River and its tributaries may be due to their having been diverted from what would seem a more natural southern course, at the time of the uplift.

A. H. PURDUE.

UNIVERSITY OF ARKANSAS,
Fayetteville, Ark.

THE DISCOVERY OF A NEW FOSSIL TAPIR IN OREGON

A FAIRLY complete phylogenetic series of early Miocene tapirs has been made known to science through the researches of Messrs. Wortman,[1] Earle, and Hatcher.[2] Between these ancestral forms, referable to the genus *Protapirus*, and the living species is a gap in the line of descent which has remained unbridged until the fortunate discovery of the form presently to be described.

Our knowledge of the tapir phylum since the White River epoch may be summarized in a few words. In 1873, Dr. Joseph Leidy[3] described under the name *Lophiodon oregonensis*, two imperfect superior molars obtained by Professor Thomas Condon at Bridge Creek, Oregon. Two species have been described by Professor Marsh,[4] which he refers to the genus *Tapiravus: T. rarus* from the Loup Fork of the Rocky Mountains, and *Tapiravus validus* from the Miocene of New Jersey. From the brevity of the description and the lack of figures, these species are practically indeterminate. Remains of tapirs belonging to the existing genus are known from the Quaternary gravels of California,[5] and have been described from several localities in the eastern states.

During the summer of 1900, Professor John C. Merriam and Mr. V. C. Osmont, of the University of California, while collecting in the fossil beds of the John Day valley, Oregon, obtained the bones which form the subject of the following discussion. The remains are from the Promerycochœrus horizon (Upper John Day) exposed on the bank of the John Day river, beneath the Columbia basalt, to the west of Spray post-office, Wheeler county, Oregon. In a recent paper,[1] Professor Merriam named the beds of the Upper John Day the Paracotylops beds, basing the name on the new genus *Paracotylops*, proposed in the same paper by Dr. W. D. Matthew for the typical Oreodonts of this horizon. In the numbers of the *American Journal of Science* for last December and January, a paper by Mr. E. Douglass appeared in which these Oreodonts were provisionally named *Promerycochœrus*. Neither Professor Merriam nor Dr. Matthew read this article before the publication of Professor Merriam's paper, and consequently did not notice the new name. It now appears that *Promerycochœrus* should be retained as a generic name, and consequently, at Professor Merriam's suggestion, the name of the beds of the upper division has been changed from Paracotylops to Promerycochœrus beds.

---

[1] J. L. WORTMAN and C. EARLE, "Ancestors of the Tapir from the Lower Miocene of Dakota," *Bull. Am. Mus. Nat. Hist.*, Vol. V, p. 159.

[2] J. B. HATCHER, "Recent and Fossil Tapirs," *Am. Jour. Sci.*, 4th ser., Vol. I, p. 161, 1896.

[3] U. S. Geol. Surv. of the Territories, Vol. I, p. 219, Pl. II, Fig. 1.

[4] O. C. MARSH, *Am. Jour. Sci.*, Vol. XIV, p. 252, 1877.

[5] J. D. WHITNEY, "Aurif. Gravels," *Mem. Mus. Comp. Zoöl.*, Harvard, Vol. VI, p. 250; W. P. BLAKE, *Am. Jour. Sci.* Vol. XLV, p. 381.

The type specimen (No. M 934, Univ. of Cal. Pal. Mus.) comprises several superior incisors; the lower jaw lacking the posterior portion, with representatives of all the inferior dentition excepting the canines and the third molar; the proximal portion of the left humerus; the left radius; the scaphoid, lunar, magnum, and unciform of the right carpus; three metacarpals of the same side, and a few phalanges. The bones are those of a single individual of a new species of the genus *Protapirus*, for which the name *Protapirus robustus* is proposed. It is considerably larger than any of the White River species of *Protapirus*, and would approximate in size the most specialized living tapir, *Elasmognathus bairdii*. The lower jaw is represented about one-half natural size in Fig. 1. The symphysial region was found in place, imbedded in a buff colored tuff so characteristic of the Upper John Day beds that the expression "buff beds" was used as a convenient field term for this horizon. The other bones lay loose on the surface in the immediate vicinity.

---

[1] "A Contribution to the Geology of the John Day Basin," *Bull. Dept. Geol., U. of Cal.*, Vol. II, No. 9, p. 296; JOUR. GEOL., Jan.-Feb., 1901, p. 72.

The dentition.—The superior incisors are larger than the corresponding teeth in *Elasmognathus bairdii.* The inferior incisors are slightly smaller than the superior. Both series have the crowns somewhat cupped, especially so in the superior incisors. The first and second inferior incisors are of equal size, while the third is two-thirds as large as those preceding it. The crowns of both canines are broken off, but the diameters of their roots, measured on the alveolar borders, are greater than the corresponding parts of the larger incisors. A long diastema succeeds the canines. The premolars have their anterior cusps united into transverse ridges, slightly notched at the summit. In all except the second premolar, the ridges are perpendicular to the long axis of the jaw. They are equally developed on the third and fourth premolars. Posterior cross crests are not developed on any of the premolars. In the second premolar, the protoconid is larger than the deuteroconid and is situated farther forward than the latter. In the succeeding premolars, these cusps are of the same size and are situated directly opposite each other. The tetartoconid of the premolars is smaller than the metaconid. The latter cusp is united with the inner side of the base of the protoconid by a ridge. This structure is also found in the molars, all of which have two cross crests. The posterior crest in the first and second molars is somewhat oblique to the axis of the jaw. The third molar is too imperfectly preserved to describe. Anterior and posterior cingula are present on all the molars and premolars. Traces of an external cingulum are found at the outer end of the transverse valley in all except the second premolar. In this tooth the paraconid is very large, uniting by a ridge with the protoconid. In the remaining premolars the paraconid is replaced by a style rising but little above the level of the anterior cingulum.

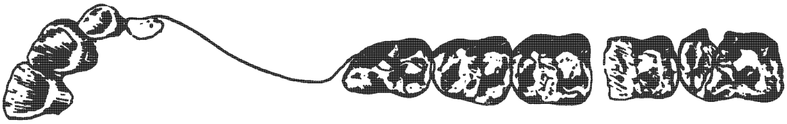


FIG. 1.

The jaw.—The inferior border of the jaw is parallel with the alveolar border. The symphysial portion rises at a low angle, much less than in the tapir. The flatness of this angle is perhaps due in part to a slight amount of crushing which the specimen has sustained. The posterior border of the mental foramen is directly below the anterior border of the second premolar.

The fore limb.—The humerus and radius have about the same shape as in the tapir. The deltoid ridge of the former is broken off, so that it is impossible to say whether it was hooked or not. The shaft of the radius is more strongly curved than the corresponding element in *Protapirus validus* as figured by Hatcher,[1] but a part of the curvature may be due to distortion. The carpus does not call for special description, not differing materially from that of *Protapirus obliquidens*. W. & E. The anterior contact of the lunar and magnum is still small, as in the White River species. There were four digits in the manus, the length of metacarpals III, IV, and V being about the same as in *E. bairdii*, but less robust. In shape they correspond closely with the metacarpals of the latter, except that the proximal portion of the fifth is inclined at a greater angle to the shaft of the bone than in the living form. The phalanges, which are of the second row, are shorter and less robust than those of the tapir.

Phylogenetic position.—The remains just described indicate an animal much larger than any of the White River species of the same genus. The structure of the molars and premolars suggests *Protapirus validus* as a probable ancestor. There are, however, several differences. In addition to the considerable difference in size, the third premolar of *P. robustus* has the anterior cross crest vertical to the long axis of the jaw, while in *P. validus* it is somewhat oblique. The diastema, as in *P. validus*, is shorter than in *Elasmognathus*, while the mental foramen has moved slightly posterior to the position it occupies in the White River ancestor. Gradations between the two types probably occur among the as yet unknown tapirs of the Lower and Middle John Day.

---

[1] *Loc. cit.*, p. 167, Fig. 1.

MEASUREMENTS OF PROTAPIRUS ROBUSTUS

Length of inferior molar-premolar series	128 to 130^{mm}
Length of inferior premolar series	60
Length of inferior molar series (approximate)	70
Length of diastema	46
Length of symphysis measured on lower side	71
Depth of ramus below alveolus of Pm. 2	48
Depth of ramus below alveolus of Pm. 4	49
Depth of ramus below alveolus of M. 3	43+
Length of radius	181
Breadth of proximal end of radius	45
Breadth of distal end of radius	39

In this connection, may be mentioned a second specimen, (No. M 1525 University of California Pal. Museum), representing probably another new species, obtained by the writer in the uppermost beds of the John Day system, on Johnson Creek, Grant county, Oregon. The horizon is considerably higher than that from which *Protapirus robustus* was obtained, and appears to be faunally distinct. It is characterized by the remains of numerous individuals of a camel belonging to the genus *Protomeryx* and by a rodent generically new. The tapir remains are of a young animal and are not complete enough to characterize specifically. They comprise fragments of a jaw with which three incisors and the second inferior premolar are preserved. The two large incisors, apparently the inferior median pair, are two-thirds as large as the corresponding teeth in *P. robustus*. They are spatulate in shape and slightly cupped. The anterior face is marked by delicate growth lines. The third incisor is an exceedingly small tooth with the crown 3½^{mm} broad. Imperfect preservation of the symphysial region renders it impossible to make any statement regarding the canine. The second premolar of the right side is the only one of the cheek teeth perfectly preserved. This tooth is entirely unworn, and was just appearing through the gums at the time of the animal's death. In this tooth, the tetartoconid is much larger than in *P. robustus* and the junction of the metaconid with the tetartoconid is much more complete, forming a cross crest but slightly notched. A ridge joins the former cusp with the middle of the anterior cross crest. The protoconid is considerably anterior to the deuteroconid and as in *P. robustus* is united with the paraconid by a ridge. The anterior cross crest is sharply notched, but this structure would probably assume the character of the anterior cross crest in *P. robustus* with the wearing down of the deuterocone by use. External cingula appear at the outer margin of the median valley and on the external side of the paraconid. A posterior cingulum is also developed.

MEASUREMENTS

Width of the crown of first inferior incisor	9½ mm
Width of the crown of third inferior incisor	3½
Length of the first premolar crown, antero-posteriorly	15½

WM. J. SINCLAIR.

PALÆONTOLOGICAL LABORATORY,
University of California.

GLACIAL WORK IN THE WESTERN MOUNTAINS IN 1901.[1]

DURING the season of 1901 some time was given to the study of Pleistocene problems in the western mountains. Four small parties, beside the writer, were in the field. The work of three of the four parties was the somewhat detailed study of selected areas, and was intended to make known the general conditions of glaciation at several somewhat widely separated localities. When a sufficient number of selected areas have been studied similarly, the results will afford a basis for preliminary conclusions concerning the course of Pleistocene history in the western mountains, and will be helpful in guiding future work. The work of this summer was intended as the beginning of study looking to this end.

The writer spent about six weeks in the region, mostly in association with the parties referred to. One party was in northwestern Montana, east of the Rockies; one farther west, on the western side of the Rockies, in northwestern Montana, northern Idaho, and eastern Washington; one in the Wasatch Mountains; and one in the mountains of New Mexico, a few miles northeast of Santa Fé.

The following brief summary will give some idea of the work done:

NORTHWESTERN MONTANA, EAST OF THE ROCKIES.

Mr. Fred H. H. Calhoun, accompanied by Mr. Bruce McLeish, spent three months in the northwestern part of Montana. The area studied, some 8000 square miles in extent, lies just south of the 49th parallel, and just east of the Rocky Mountains. It is the area in the angle between the Continental ice sheet from the northeast, on the one hand, and the Cordilleran ice sheet from the northwest, and the mountain glaciers from the west, on the other.

---

[1] Published by permission of the Director of the U. S. Geological Survey.

The moraine formed by the northeastern ice sheet of the Wisconsin epoch was traced from Fort Benton, *via* Choteau, to the point where it crosses the 49th parallel, about longitude 112° 20′. From this point the moraine bends to the west and continues in this direction to the Watertown River, where it turns to the north, its course being nearly parallel to the mountains.

The moraines of fourteen glaciers from the Rocky Mountains were mapped. The recessional moraines of both the valley and continental ice masses were studied as far as time permitted. Study was also made of the extent of valley trains and outwash plains, and of the lakes which existed in front of the ice during the glacial period.

Among the results of the work, the following may be mentioned:

1. The westward and southwestward extension of the Wisconsin drift is greater than had been supposed.

2. The till of the northeastern ice sheet and that of the mountain glaciers overlap just south of the 49th parallel, between the meridians of 113° 10′ and 113° 15′. At no other point south of the boundary line did the ice from opposite directions occupy the same territory; but in Two Medicine Valley (latitude 48° 30′) the ice from the east advanced to within two miles of the position occupied at an earlier time by the ice from the mountains.

3. The ice sheet from the northeast reached its most advanced position after the valley glaciers from the west had retreated, for the drift of the former overlies the drift of the latter at various points, both north and south of the national boundary. In some cases the till from the northeast overlies the till from the west. This is true in the locality mentioned under 2, and farther north in the valleys of St. Mary's River, Belly River, and Lees Creek. In other places the till from the east overlies fluviatile deposits connected with the western drift, but extending down the valleys some miles beyond (east of) the ends of the mountain glaciers. In still other cases lacustrine

THE FORMATION AS THE BASIS FOR GEOLOGIC MAPPING

In a recent number of this Journal Mr. Bailey Willis, in a paper on "Individuals of Stratigraphic Classification," has restated and rediscussed the problem which must be solved before cartographic work of any magnitude can be planned. This problem involves a careful consideration of the relative weights to be assigned, in any system of classification to be used on geologic maps, to faunal, lithologic, and chronologic (successional) characters. Mr. Willis discusses the question in its various aspects, and his final decision is that the lithologic unit (formation) is best adapted to the requirements of the cartographer.

While agreeing, in the main, with the conclusions reached by Mr. Willis, it seems desirable to call attention to certain arguments, not specifically mentioned by him, which may be adduced in support of those conclusions; and, further, to examine the results of the application of the proposed system of classification to some particular cases of interest.

Before commencing the discussion of this question I wish to acknowledge my indebtedness to Dr. F. J. H. Merrill, director of the New York State Museum, who has greatly aided me, with both criticism and advice, during the preparation of this paper.

THE NECESSITY FOR UNIFORMITY

Though the formation, defined primarily by lithologic characters, was officially adopted in 1889 as the cartographic unit of the United States Geological Survey, in practice it has not entirely superseded other units of classification. Great variety exists in the practice of the various state geological surveys, as is indicated by their official maps; and greater variety, as might indeed be expected, in unofficial maps accompanying papers on areal geology, even though the authors be connected with surveys whose official practice is uniform.

In considering the representation on a map of the geological features of a small, isolated area, the question of the taxonomic unit to be employed is usually of minor importance; though even in this case, as shown later, there would seem to be good reasons for the adoption of the lithologic individual as this unit. The interest attaching to this question increases directly with the size of the area to be mapped; and the problem becomes of paramount importance when the independent work of several geologists is to be combined, as in the compilation of a geologic map of an entire state or other large area.

In view of these facts, and of the slow but steady spread of the geologic-folio work carried on by the United States Geological Survey, it would seem necessary that the various local surveys should adopt the same general system of classification for map work. In the present state of our knowledge, detailed chronologic classification, the unit for which would be the epoch[1] of earth-history, is impossible; and the problem of unification is therefore resolved into the choice between two alternative systems, based respectively upon biologic and lithologic characters. In the opinion of the writer a geologic survey, whether state or national, can best accomplish the work for which it is intended by adopting as its cartographic and taxonomic unit the formation, defined as a lithologic individual.

THE RELATIVE SCIENTIFIC VALUES OF BIOLOGIC AND LITHOLOGIC UNITS

For the purposes of the present discussion it is necessary to point out that our knowledge of the two histories (*i. e.*, of sedimentation and of life), so far as that knowledge can be expressed on maps, is decidedly different in grade. The present phase of earth-history may be examined for a determination of the truth of this statement. We can map without difficulty the topographic features of the earth; and the possible accuracy and precision of such mapping is limited only by the consideration of expense. Moreover, we are able in most cases to discuss topographic features in terms of causality.

---

[1] The word epoch is here used in an entirely general sense.

With regard to the present biologic condition of the earth our knowledge is much less definite. Mapping the distribution of existing faunas or floras is not practicable in the present state of our knowledge of biotic[1] distribution, except in a very general way; anything like a detailed map is impossible. This condition is due partly to the expense of collecting sufficient data on the range of the different species of plants and animals. Most of the difficulty, however, arises from the fact that the principles underlying and regulating animal and plant distribution are still far from being well understood, though of late years great advances have been made in that direction.

If our knowledge is thus imperfect with regard to the existing biota,[1] our knowledge of the facts and causes of its distribution during past ages is still less definite. It is noteworthy that two of the most successful attempts[2] to account for biotic distribution and evolution in periods antedating the present have been the work of geologists specializing in physiographic work, a branch which necessitates lithologic rather than biologic discriminations.

Obviously, the paleontologic record must always be more defective than the lithologic; for fossils are not always found where rocks are exposed. In addition to gaps occurring because of local lack of fossils, two periods are particularly incapable of being treated on a biologic basis; one immensely long period at the commencement of geologic history, and one short but highly important period immediately preceding the beginning of written history.

With regard to the relative values of the biologic and lithologic units as measures of absolute time, the case is somewhat in favor of the latter unit; for the relation existing between time taken in deposition and thickness of formation is much more traceable than that between extent of variation and time taken in evolution.

---

[1] Biota = the sum of the fauna and flora of a region. *Cf.* STEJNEGER, *American Naturalist*, February 1901, p. 89.

[2] T. C. CHAMBERLIN, "Systematic Source of Evolution of Provincial Faunas," JOURN. GEOL., VI, pp. 597–608, 1898. J. B. WOODWORTH, "Relation between Base-leveling and Organic Evolution," *American Geologist*, XIV, pp. 209–235, 1894.

In considering the adoption of a basis for geologic mapping the biologic unit has, therefore, no antecedent claim to special consideration on scientific grounds; and its value can be compared directly with that of the lithologic unit in regard to their relative practicability and utility.

THE RELATIVE PRACTICABILITY OF THE TWO SYSTEMS

A lithologic unit can usually be so described and defined as to be readily identified by any future worker in the same or an adjoining area through which the formation extends.

It should also be noted that all geologists substantially agree upon the use of the terms in which lithologic individuals are defined, and will consequently agree closely in their valuation of any series. "Limestone," "sandstone," "slate," "conglomerate," all have fairly definite meanings, and it is improbable that terms such as these are used in very different senses by different geologists. The biologic unit, on the other hand, is rarely capable of being so described or defined as to be acceptable to all paleontologists. The difference is that the lithologic individual is a fact; the biotic individual, as commonly described, is a fact plus an interpretation; and while there may be substantial agreement as to the facts in any given case, it is but rarely that the interpretations will coincide.

The Hudson formation in the vicinity of Albany, N. Y., presents an excellent example of some of the practical difficulties encountered in attempting to represent faunal distinctions on a map; and a brief sketch of the conditions may be of interest in the present connection.

The "Hudson River group" of the earlier classifications—the "Hudson formation" of the present system of nomenclature—comprises in the central portion of the Hudson River valley, where it is best developed and exhibited, a thick and extensive series of shales, with interbedded sandstones and occasional thin beds or lenses of limestone. This series is well shown along the banks of the Hudson River, extending almost uninterruptedly from Fort Edward to Cornwall. Faunal differences justify the paleontological division of the "group" into four stages, of which the two lower carry a fauna which would correlate them with the Trenton (using that term in its paleontological significance), while the other two represent respectively the Utica and Lorraine beds of the Mohawk valley. This division into stages, however, is and must be largely theoretical, for it cannot well be carried out in practice on a map. Fossils, especially of species which can be regarded as of taxonomic importance, are neither profusely nor regularly distributed throughout the beds in question. Outcrops carrying characteristic fossils are too few and far between to warrant mapping the area, on a paleontological basis, on any large scale. The lithologic differences which occur in the group have no stratigraphic or cartographic value, being too slight and variable to admit of separate representation on a map.

Modern geologic mapping, especially if the base of the map is to be a topographic atlas sheet, in order to make adequate returns for the expense involved, must be accurate within the limit fixed by the scale of the map.

The production of a geologic map is necessarily accomplished by the exercise of two functions, observation and inference. Observation involves the location of outcrops and lithologic boundaries with reference to fixed points in the control of the map, and is therefore purely a matter of engineering. The exercise of the function of inference is necessary in order to indicate the positions of boundaries concealed by superficial material. Inferences in relation to such matters are dependent for their accuracy on the training and judgment of the geologist; his appreciation of the relations existing between structure and topography, and his knowledge of the geometric effects of dip, pitch, etc., in determining the position, both horizontal and vertical, of a concealed boundary line.

Other things being equal, the determination of the altitude and geographic position of a given point is dependent upon the engineering skill of the observer; and the cartographic unit to be employed does not seriously affect this phase of the work of mapping. With regard to inference, however, this is not the case. No necessary relation exists between a biologic unit and the topography or structure of the area in which it occurs. On the other hand, topography, structure, and the lithologic unit are in general closely related. Recognition of these relations makes it possible to draw inferences concerning the position of the concealed boundary of a lithologic unit from the geologic structure and topography of the area discussed.

THE RELATIVE UTILITY OF LITHOLOGIC AND BIOLOGIC MAPS

A lithologic unit is normally also an economic unit, whereas there is no necessary relation between the biologic unit and the economic importance, or lack of importance, of the rocks containing a given biota. Though this argument may be regarded by some as of less weight than one based on purely scientific grounds, it is nevertheless valid, as applied to the question under discussion. It should not be forgotten that no geologic survey has ever been instituted, save for economic reasons; that the chief argument that can be used to obtain state support for such surveys is the direct economic return to the public; and that simple justice demands, in return for this support, that the geologic results obtained be placed in such a form as to be of the greatest possible use to that public.

The lithologic unit is also generally related to geographic forms in a very definite manner, as well as to geologic structure. The effects of these relations upon the actual work of mapping have been discussed. Here it is only necessary to point out that both topography and structure are often of economic importance. A map based on a unit which bears some definite relation to them is, therefore, of greater value from an economic standpoint than if the unit be one not so related.

THE DIFFICULTIES IN MAPPING ON THE LITHOLOGIC BASIS

Difficulties will certainly be encountered in mapping any large area on a lithologic basis, but these difficulties will arise rather from differences in the interpretation of the rules for the nomenclature of the units than from any defects in the system itself. Certain cases of interest in this connection are discussed below:

Case 1.—The case is that cited first by Mr. Willis (p. 563). A shale passes along the strike into a limestone which retains identical stratigraphic associations. "Being exactly continuous stratigraphic units, they should retain the same geographic name on grounds of convenience and simplicity." Considered as a stratigraphic unit, the two would be discussed as the "X" formation. In order to preserve all the advantages of the lithologic system of classification, however, the limestone phase should be differentiated, in both discussion and mapping, from the shale phase; their respective names being then the "X" limestone and the "X" shale. The term "phase" seems to serve a useful purpose in this connection, and the present writer, therefore, proposes it for use in marking variations of sedimentation or of metamorphism within the stratigraphic unit. When used later in this paper, it will be with this restricted and definite meaning.

This case is illustrated excellently in New York state and western New England, in this example the phases representing variations in metamorphism. The Hudson shales of the central part of New York state are progressively metamorphosed to the eastward, becoming first slates and then mica-schists. The schistose phase has been called, in Massachusetts, the "Berkshire schist;" in southeastern New York, by Merrill, the "Manhattan schist," while Dale has described the intermediate phases as "Hudson slates." Throughout the entire area, though differing thus in character because of variations in metamorphic action, the rocks are essentially continuous stratigraphically; and recognition of this fact has led to the recent proposition to eliminate the names Berkshire and Manhattan, and denote the various phases of the Hudson formation by the term "Hudson shale," "Hudson slate," "Hudson schist." This system of nomenclature, while recognizing the essential stratigrapic equivalence and continuity of the various phases, allows these phases to be discriminated from each other on lithologic grounds. On maps this discrimination can best be shown by the use of some of the various overprints used to denote metamorphism.

Case 2.—The second case noted by Mrs. Willis is that of a "shale grading into a limestone with prolonged overlap, so that the two rocks must be discriminated in one area. Not only are they lithologically different but they have different stratigraphic associations, and they should receive distinct" formational names. As noted under the preceding case, this is the condition which usually obtains where there is a horizontal gradation in character of sedimentation. The writer believes that Mr. Willis has here suggested the proper treatment of the question, but wishes to point out an actual case of some areal importance in which this ruling has not been followed.

The example occurs in the northwestern part of Massachusetts. To the west of Hoosac Mountain, the Cambrian quartzite is overlaid by Stockbridge limestone and this in turn by Hudson (Berkshire) schist; on and east of the mountain the limestone does not appear. It has been generally assumed that the schist of the mountain represented both the Berkshire schist and the Stockbridge limestone, and the name "Hoosac schist" has been applied to it in several publications.

What the writer wishes to point out is that, under the proposed rules, the name at present used for one of those formations would seem to be untenable. For, if the eastern (Hoosac) schist represents both the Berkshire schist and Stockbridge limestone, the case becomes the same as 2, and in that case all the schist should be called Berkshire and all the limestone Stockbridge. If the transition be considered sudden, then it exhibits a slight modification of case 3, and still all the schist is Berkshire schist and all the limestone Stockbridge limestone. If the relations at Hoosac Mountain be referable to overlap, of the earlier ice epoch with the earlier wide extension of the Bonneville waters cannot as yet be asserted, although the data at hand strongly suggest the contemporaneity of the early expanded stage of Lake Bonneville and the early glaciation.

THE MOUNTAINS NEAR SANTA FÉ

Messrs. John E. Webb and William A. Averill spent about one month in the mountains of New Mexico, a few miles northeast of Santa Fé. The area studied was the Santa Fé range of the Rockies, which traverses the northeastern portion of New Mexico, running in a general north-northeast, south-southwest direction through the adjacent parts of Santa Fé, Rio Arraba, Mora, and San Miguel counties, between the parallels of 35° 45′ and 36°, and the meridians of 105° 35′ and 105° 50′. The aggregate area comprises about 250 square miles.

The height of the range in the area studied varies from 7000 feet to 13,306, feet, the latter being the altitude of the highest of the Truchas peaks. The altitude which seems to have been necessary for the generation of glaciers was 11,700 to 12,000 feet. The following peaks attained the requisite height: Lake peak, 12,380 feet; Baldy peak, 12,623 feet; Pecos Baldy (Cone peak?), 12,550 feet; Jicarilla peak, 12,944 feet; and the Truchas group, the highest peak of which is 13,306 feet. Clear evidence of glaciation was not seen on lower peaks, though it cannot be said that many of the lower peaks were studied in the detail necessary to demonstrate the complete absence of glaciation.

Heading against these peaks and their connecting ridges, fifty cirques bearing evidences of glaciation were observed. Névé fields, with incipient motion, existed at some points where well-formed glaciers did not develop. Sixteen of the cirques are in the group of mountains (Lake, Baldy, and associated ridges) at the head of Santa Fé Creek; seven in the Pecos Baldy group; twelve among the Truchas peaks; and fifteen about Jicarilla peak, and the ridge between it and the Truchas peaks. Of these cirques, twenty-five open toward the east, thirteen toward the north, seven toward the south, and five toward the west. The cirques range from one-fourth of a mile to two miles in width, and from one-eighth of a mile to two and one-half miles in length, and from 150 to 1000 feet in depth. Most of them contain lakes or ponds, some of them as many as six, and almost all contain flats or bogs, indicating the former existence of standing water, where there is none now. The total number of ponds and lakelets seen was about eighty. Since they were seen in the rainy season, the number of permanent bodies of standing water may be less.

The longest glacier track studied is in the valley of the Santa Fé Creek. The ice emanating from three cirques united to form a single glacier which Messrs. Webb and Averill think extended some seven miles down the valley, its lower end reaching down to an altitude of about 9200 feet, the lowest altitude, so far as seen, to which the ice descended. The largest area of glaciation from a single source is that on the east side of the Pecos Baldy group, in the valley of Jack's Creek, while the largest continuous area of glaciation (to which the ice from several sources contributed) is that along the group of mountains at the head of Santa Fé Creek.

The moraine matter left in the cirques, and in the valleys below them, often has a pronounced hummock-and-hollow topography. Its composition varies from point to point. The chief accumulations are in the bottoms of the valleys. The morainic matter is often disposed in ridges most commonly roughly parallel to the axes of the valleys and to the direction of ice movement, but often oblique or even at right angles to this direction.

Striæ were found on *roches moutonneés* in several places, while smoothed and polished rock surfaces are of frequent occurrence.

The higher ridges and peaks of the glaciated regions are serrate, but serrate crests are confined strictly to the higher parts of the range. Serration often characterizes the tops of the mountains, on the sides of which the glaciated cirques lie.

OTHER OBSERVATIONS

In addition to the foregoing work, some further data were gathered at several points, touching Pleistocene geology in the West. It was found that loess has somewhat extensive development in eastern Washington and northeastern Oregon, though its limits were not determined. It is widespread in Douglas, Lincoln, Whitman, Columbia, Walla Walla and probably Spokane counties, Washington. It is very generally distributed over the northern part of Umatilla county, Oregon. In geographic distribution it seems to correspond, in a general way, with the great wheat belt of the states mentioned. In topographic distribution, it has the general habit of the corresponding formation in the Mississippi basin; that is, it has a preference for considerable elevations. So far as seen, however, its disposition to follow streams is less pronounced than in the Mississippi basin east of the Missouri. Its variations in composition and structure, too, are similar to those of the loess of the interior. Its thickness is very variable, and for the most part undetermined, but locally it is at least twenty-five to thirty feet thick, and its maximum is probably considerably more. In many places, as at Bolles Junction (Walla Walla county), it abounds in calcareous concretions of the usual loess type. In other places, as at Alto (Columbia county), it assumes the columnar structure, so characteristic of the loess of some other localities where the formation is well known. In many places, it constitutes the entire mantle rock. In some places it is associated with sand, which may be either beneath it or interbedded with it; and in other localities it contains considerable beds of volcanic ash. The sand and volcanic ash associated with it are sometimes distinctly stratified. In some cases, the stratification is clearly the work of wind, but in others this was not evident. The impression gained was that much of the loess seen is of eolian origin.

Observations on glaciation were made at several points, aside from those enumerated in the preceding pages. Data sufficient for the intelligent direction of future Pleistocene work were gathered for a number of localities where detailed work in the near future seems desirable. In addition to preliminary studies of this sort, glaciation was found to have occurred in some localities from which it has not heretofore been reported. For example, it was found that glaciers affected the north slope of both the Spanish Peaks of Colorado. These mountains, 12,708 and 13,623 feet high respectively, appear to have represented about the limiting conditions for glaciation, for the glaciers of both mountains were small, and confined to their northern slopes. One of the limiting conditions here was doubtless the small area which could serve as a catchment basin on either peak. Had the areas of these mountains been larger, more considerable glaciation would doubtless have been developed at this altitude.

It was found, among other things, that the detailed study of glacial problems will locally have an important economic bearing. An extensive placer mining plant is being established at Breckenridge, Col., to wash the glacial moraine matter of the Blue River valley, and the gravels of the valley train below.

ROLLIN D. SALISBURY.

REVIEWS

Preliminary Description of the Geology and Water Resources of the Southern half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. By N. H. DARTON. [Extract from the Twenty-first Annual Report of the U. S. Geol. Surv., 1899–1900, Pt. IV, Hydrography; pp. 489–599; Plates LVIII–CXII; Washington, 1901.]

THE topics discussed in this paper are topography, stratigraphic-geology, geologic structure, geologic history, water resources, minerals, soils, climate and timber. The Black Hills rise out of the Great Plains as a small group of forest covered mountains several thousand feet high. Their central area, composed of mountains and parks, is of crystalline schists and granites. Bordering the old rocks is a belt of limestone plateaus surrounded in turn by the Red Valley, a depression resulting from the etching out of a layer of softer rock — the Spearfish formation of Triassic age. Beyond the valley and concentric with it is the hogback range, due to a hard sandstone not weathered down. Still farther outward are the Plains. Careful descriptions of the lithologic characters and the distribution of each formation follow; in fact the paper is descriptive rather than theoretic, but does not fail to call attention to broad features and to make generalized statements.

The oldest sediments are Cambrian. They are probably of later Cambrian time and give one more item of evidence leading to the conclusion that Cambrian time was one of extensive submergence. Here Cambrian sands were deposited along seashores and in estuaries with gradual submergence and probable ultimate covering of the crystallines with sediments of this age. The chief evidence is the presence of fine grained deposits in the Upper Cambrian such as are not formed near land. At present no Silurian or Devonian strata occur. The reason is problematic. Either there was no deposition or else little deposition and subsequent removal. Carboniferous time began with deep water and marine conditions, and was consummated after the laying down of 800–1000 feet of rock. Triassic and Jurassic are both present and distinguishable because an abrupt change in the character of the sediments and some erosion occur at the top of the former. Cretaceous sediments have accumulated to the thickness of about 6000 feet and consist largely of shales with some sandstone and a little limestone. Tertiary rocks represented by the White River formation are mostly of clay; fuller's earth, sand, limestone, and grits occur. Still later deposits are classed under earlier and later Pleistocene beds.

The structure of the region is that of an elongated low dome with anticlinal wrinkles or spurs running off from the central area. The maximum uplift was north of Harney's Peak and amounted to 9000 feet.

One of the most admirable features of this paper is the abundance of real geographic material embodied in it. The region described is one of submaturely dissected, domed mountains in which all the sediments have been removed from the central portion leaving subdued hills and broad parks of crystalline rocks. The concentric arrangement of the different formations is due to the uplift and to the processes of erosion which though similar for all strata, have been much more effective in reducing some than others. Soft layers are found etched out, hard layers standing up, but each and every one has its peculiar forms. Thus geography follows stratigraphy.

Attempts by the author, more or less successful, to reconstruct the geography of the locality at different periods and to follow it through its phases, are persistently made, and they yield an interesting element in the work. In this connection there is a contour map showing the present relief of the upper surface of the Dakota sandstone over a part of the area. This kind of work forms a very desirable feature.

The considerable eastward dip away from the Black Hills, where most of the formations outcrop, together with other necessary features, gives good artesian conditions to this region. Many wells reaching the Dakota and Lakota sandstones flow with good water. The scanty rainfall on the plains eastward renders these wells very useful. Many streams diminish or cease by sinkage when they cross the sands. Along Cheyenne and Fall rivers there is some opportunity for irrigation — good bottom lands and reservoir space, with fair water supply.

Soils are mostly residuary from underlying rocks. Overplaced soils and sand dunes are found in places. "Sedentary soils" may be criticised. No soil is sedentary in the sense that it does not move. "Soil in place" or preferably "residual soil" more adequately carries the meaning. The relation of soils to underlying rocks, and of crops to soils make very instructive points. Considerable mineral wealth is found in coal, gypsum, and lithographic limestone in large slabs. These of sufficient size to be valuable are not obtainable elsewhere in the United States.

The notes and diagrams on climate are good but disappointing because they do not indicate the significance of the condition of the meteorologic elements from a geologic point of view. There is little utility in giving space in a geologic report to climatic notes unless some use is made of them. The climate must have characteristic influence on erosion, soil formation, soil transportation, etc. The position of volcanic ash to the eastward of the volcanoes, now extinct, just west of the Black Hills shows similarity of winds in the White River time to those of the present time.

Why cannot the U. S. G. S. reports, in discussing such a region as this, have a section on geography? It should embrace most if not all of the section here devoted to topography, but should go farther with the question, incorporating some that is said under soils, climate, water resources, etc., and then discuss the influence of relief, soil and water on products, transportation, distribution of plants and animals, man, and his various occupations.

GEO. D. HUBBARD.

EASTERN ILLINOIS STATE NORMAL SCHOOL,
Charleston, Ill.

The High Plains and Their Utilization. By WILLARD D. JOHNSON. [Extract from the Twenty-first Annual Report of the U. S. Geol. Surv., 1899–1900, Pt. IV, Hydrography; pp. 601–768; Plates CXIII–CLVI.]

THE High Plains, as defined in the first chapter, correspond approximately to the Central Plains. They form a belt extending from central Texas northward across Oklahoma and western Kansas into Nebraska, but are more characteristic in Texas because less eroded. By topographic difference they constitute a topographic unit of the great geographic unit—the Great Plains. The High Plains practically have no drainage, hence their surface is in general a dead level known locally as the "Flats."

Chapter II discusses the origin of these plains. They are the remnants of an old débris apron built in the latter half of Tertiary time, and preserved because of lack of sufficient precipitation to produce run-off. The author takes the ground that this apron of waste was deposited and arranged by streams, but shows that the streams were not of the ordinary type. A careful analysis of arid region stream work leads to the conclusion that "there is no such thing as sheet flow" in the sense of a uniform flood of water and waste, but that the more or less perfect sheet is "one of intimately lacing threads of current."

The deposits of which the plains are composed are the result of this stream work and not of still water work. As proof of the proposition, the author finds the following facts:

(1) Wide distribution, at all depths of gravels, which decrease in size from the mountains. (2) The size of these coarse materials is often that of cobbles. (3) Gravel courses run east and west and are cross-bedded—marking the channel courses of eastward flowing streams. (4) Sand bed salso occur in courses elongated east and west in the "clays." (5) Interlaced stream beds occur as shown where erosion has disclosed them. (6) Even most clay beds are thin and elongated east and west.

Mr. Johnson finds the "mortar-beds" cutting across the local bedding of sands and gravels, and he considers the beds to have been formed by the cementation of the coarse materials at the level of the ground water by salts carried down in the sinking surface water. It appears that his explanation of the distribution of water in these gravels is similar to that of water distribution in the morainic materials of Illinois and Indiana, as worked out by Leverett and others, and stated by Leverett in the Eighteenth Annual Report of the U. S. Geol. Surv. Pt. IV.

Chapter III is a discussion of the "deficiencies of climate." The climate of the High Plains is described as subhumid. It varies from humid to arid through a period of years. The author very properly states that the amount of precipitation is not the only factor in determining the climate, or even the arability of a region. The Dakota wheat fields actually have less rainfall than the Staked Plains of Texas, but the rainfall is more effective in Dakota. In Texas (1) rainfall is more spasmodic; (2) temperature is higher, increasing evaporation and decreasing relative humidity; (3) there are more hours of sunshine, and (4) greater wind movement. In the summary he reaches two conclusions which are thoroughly borne out by the facts and discussion. (*a*) A truer index of climate than rainfall is relative humidity. (*b*) Observations covering a quarter of a century indicate that no change in climate, save that of short-period oscillations, takes place. While the High Plains area is a climatic unit, it shows evidence of agreement in the series of climatic changes through Pleistocene, with the Great Basin lake fluctuations, and with the advance and retreat of the Rocky Mountain glaciers.

The fourth chapter gives a graphic picture of the boom of 1888–1893, with the subsequent disasters, and some suggestions as to what may be grown on the High Plains.

Chapter V proves the impossibility of general irrigation within the High Plains. The facts are as follows: (1) The rainfall and streams are wholly inadequate; (2) the mountain streams from the west are so loaded with waste that ponds to retain their waters would be exceedingly short-lived; (3) all mountain streams must pass through a broad, arid, fertile strip amply sufficient to utilize all their waters; (4) artesian water in very small quantity is found in the valleys, but the entire supply is altogether too small for general irrigation. This source, however, is sufficient to furnish water for a garden and ranch headquarters at occasional intervals.

In the closing pages there is a discussion of the origin of peculiar sink holes, and a theoretic explanation of the movements of underground waters. This last brings together considerable valuable material which formerly has been scattered and little known, but it presents scarcely anything new.

The author thus states his purpose at the outset, and he accomplishes his object: "To show that the High Plains, except in insignificant degree, are non-irrigable, either from streams, flowing or stored, or from underground sources, and that, therefore, for general agriculture, they are irreclaimable; but that, on the other hand, water from underground is obtainable in sufficient amount for reclamation of the entire area to other uses; that such reclamation has in fact already begun, and is in progress of gradual, but sure development; and that it will be universally profitable."

This paper will be of great service to those in the arid and subarid regions, and to those who may contemplate immigration thither, because it gives authentic information concerning fertility and water-supply there. But the value of the paper is not alone in its descriptive work. To science the able discussions of causes and effects, of climatic relations to geology, geography, and agriculture, of water-supply, etc., are the most attractive features. The pages devoted to underground water resources are specially strong. The only regret is that the paper is not finished.

GEORGE D. HUBBARD.

CHARLESTON, ILL.

The Bauxite Deposits of Arkansas. By CHARLES WILLARD HAYES, U. S. Geological Survey, Twenty-first Annual Report, Part III, pp. 435–472. Maps and plates.

COMMERCIAL deposits of bauxite have been known in Arkansas since 1890, when they were first discovered by the State Geological Survey. The present report by Dr. Hayes represents, however, the first detailed systematic study of these deposits, and its appearance when developments are just beginning in the area, makes it a very timely one.

Preliminary to the description of the Arkansas deposits proper, the report opens with a brief summary of the "distribution of bauxite deposits in the United States." The Arkansas deposits are limited to a small area twenty miles long and five or six miles wide, lying south and southwest of Little Rock, in the adjacent parts of Pulaski and Saline counties. The most important deposits of the state are grouped into two districts, with less important isolated ones between. The general geologic and physiographic relations of the region are recounted in some detail, derived largely, as the author says, from the state survey reports. Three distinct groups of rocks are made out, namely, the Paleozoic sediments in the northwest, the Tertiary and recent sediments on the southeast, and areas of intrusive igneous rocks in the two bauxite districts. The Paleozoic rocks are similarly folded and closely resemble those of the Alabama-Georgia-Tennessee area of the southern Appalachians. The region was probably several times reduced to a nearly featureless plain, and sometime after the folding, probably, during Cretaceous, the igneous rocks were, according to Williams, intruded. Beginning with the Cretaceous, the region was several times invaded by the sea and Tertiary sediments still form a considerable part of the area.

In the detailed description of the deposits, the two districts are separately described in some detail, and certain peculiarities possessed by each are pointed out. The few scattered isolated deposits are likewise described.

In the Bryant district, which is the most southwesterly one, the bauxite occurs in two distinct forms: (*a*) granitic bauxite, and (*b*) pisolitic bauxite. The granitic bauxite forms the basal portions of the beds, and in most cases rests immediately on a layer of kaolin, derived by the ordinary processes of decay from the syenite. The bauxite is spongy in texture with no trace of the pisolitic structure, but showing partial traces of the granitic structure in which the individual feldspars are replaced by a porus skeleton of alumina. It is probable, says Hayes, that this type of bauxite is in every case derived directly from the syenite by the decomposition of the feldspar and the eleolite, and the removal in solution of silica, lime and alkalis, the alumina alone remaining of the original constituents. The pisolitic type is more uniform than that of the Georgia-Alabama region and forms the upper parts of the beds. The two forms of ore are not separated, as a rule, in the same section, by any sharp and definite line.

In the Fourche Mountain district only the pisolitic type of the ore has been found, which, when nearest the syenite margin, rests on a layer of kaolin as in the Bryant district. Those deposits more distant from the syenite margin are probably interstratified with sedimentary beds of Tertiary age.

The scattered isolated deposits found between the two districts resemble in their mode of occurrence the Georgia-Alabama deposits.

The deposits are in beds or layers, which range in thickness from zero to forty feet, and have a probable average thickness of ten to fifteen feet for the two districts, and two to five feet and more in case of the isolated bodies of ore.

In chemical composition the Arkansas bauxite varies within wide limits. The granitic type is the purest, and in selected samples contains less than 3 per cent. of silica and 1 per cent. of iron oxide, and corresponds in composition to the formula $Al_2O_33H_2O$ — the trihydrate of alumina. In the white bauxitic kaolins the silica ranges as high as 20 to 30 per cent., and in extreme cases the iron oxide reaches 50 per cent. in some of the highly ferruginous types of the ore.

Concerning the origin of the Arkansas bauxite deposits Dr. Hayes says that they are so intimately associated with the igneous rocks of the region that genetic relationship between the two is at once suggested. The characteristic pisolitic structure of the upper portion of the deposits indicates chemical precipitation. The granitic bauxite forming the lower or basal portions of the beds, and the bowlders, are evidently of a different origin. The bauxite was probably laid down on the syenite rather than on the kaolin, as there is no indication that the kaolin is an intermediate product between the fresh syenite and the bauxite.

In his report on the igneous rocks of Arkansas Dr. J. Francis Williams suggests two theories for the accumulation of the bauxite. First, that the bauxite was formed by the decomposition of a bed of clastic material, derived principally from the syenite. The second, which he regarded as the most probable one, involved the action of the waters of the Tertiary sea on the still highly heated igneous rocks, in which, under high temperature and pressure, the constituents of the syenite were dissolved and brought to the surface in solution, the water emerging as hot springs. In the discussion of these theories Dr. Hayes points out serious difficulties to both.

In the last part of the report Dr. Hayes treats of the "Economic Relations" under "Development;" "Amount of Ore," which includes a tabular statement of the estimate of the amount of ore in the Arkansas bauxite region, and, according to the author's calculations, shows the total amount estimated in outcrops to be 6,608,500 long tons, and the total amount under cover 43,711,200 long tons; "Quality of the Ores;" and "Mining and Preparation of the Ore for Market."

THOMAS L. WATSON.

DENISON UNIVERSITY,
Granville, Ohio.

RECENT PUBLICATIONS

—ADAMS, CHARLES C. Baseleveling and its Faunal Significance, with Illustrations from Southeastern United States. [Reprint from The American Naturalist, Vol. XXXV, No. 418, October, 1901.] Ginn & Company, Boston, 1901.

—BAKER, FRANK COLLINS. Some Interesting Molluscan Monstrosities. Transactions of the Academy of Science of St. Louis, Vol. XI, No. 8. Issued November 26, 1901.

—BLASDALE, WALTER C. Contributions to the Mineralogy of California. [Bulletin of the Department of Geology, University of California, Vol. II, No. 11, pp. 327–348.] Berkeley, November, 1901.

—COLEMAN, A. P. Glacial and Interglacial Beds Near Toronto. [Reprinted from the JOURNAL OF GEOLOGY, Vol. IX, No. 4, May–June, 1901.] The University of Chicago Press.

Marine and Freshwater Beaches of Ontario. [Bulletin of the Geological Society of America, Vol. XII, pp 129–146.] Rochester, March, 1901.

—COLLIE, GEORGE L. Physiography of Wisconsin. [Reprinted from the Bulletin of the American Bureau of Geography, Vol. II, No. 3, September, 1901.] Winona, Minn., 1901.

—Congrès Geologique International. Comptes Rendus de la VIII^e Session, en France. Imprimerie Le Bigot Frères, Lille. Paris, 1901.

—DARTON, NELSON HORATIO. Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. [Extract from the Twenty-first Annual Report, United States Geological Survey, 1899–1900. Part IV—Hydrography.] Washington, 1901.

—DINGES, J. Textbuch zum Relief der Nördlichen Kalkalpen. 1:50000. A. Fackler, Mindelheim (Südbayern), 1901.

—DUBOIS, EUGENE. Paradoxe klimatische toestanden in het Palæozische tijdvak, beschouwd in verband met den vroegeren aard der zonnestraling. [Overgedrukt uit de Handelingen van het Achtste Nederlandsch Natuur- en Geneeskundig Congress.]

—ECKEL, EDWIN C. The Portland Cement Industry in New York. [Published, by permission of the State Geologist of New York, in Engineering News, May 16, 1901.]

The Snakes of New York State: An Annotated Check List. [Reprint from the American Naturalist, Vol. XXXV, No. 410, February, 1901.] Ginn & Company, Boston, 1901.

—FINSTERWALDER, S., ET E. MURET. Les Variations Périodiques des Glaciers. Sixième Rapport, 1900. [Extrait des Archives des Sciences physiques et naturelles, T. XII, 1901.] Librairie Georg & C^{ie}., Genève. 1901.

—GOULD, CHARLES NEWTON. The Dakota Cretaceous of Kansas and Nebraska, and other papers. [From Vol. XVII, Transactions Kansas Academy of Science.] Topeka, 1901.

—HARKER, ALFRED. Ice-Erosion in the Cuillin Hills, Skye. [Transactions of the Royal Society of Edinburgh, Vol. XL, Part II (No. 12).] (With a map.) Robert Grant & Son, 107 Princes Street, Edinburgh; and Williams & Norgate, 14 Henrietta Street, Covent Garden, London, 1901.

—HOBBS, WILLIAM HERBERT. The Newark System of Pomperaug Valley, Connecticut. With a Report on Fossil Wood by F. H. Knowlton. [Extract from the Twenty-first Annual Report U. S. Geological Survey, 1899–1900, Part III — General Geology, Ore and Phosphate Deposits, Philippines.] Washington, 1901.

The River System of Connecticut. [Reprinted from the JOURNAL OF GEOLOGY, Vol. IX, No. 6, September–October, 1901.] The University of Chicago Press.

—KEILHACK, CONRAD. Geologisch-morphologische Übersichtskarte der Provinz Pommern. Mit Benutzung der Aufnamen der Geologischen Landesanstalt entworfen. In Vertrieb bei der Königlich Preussischen Geologischen Landesanstalt u. Bergakademie, Berlin, N. 4, Invalidenstrasse 44.

—KUNZ, GEORGE F. The Production of Precious Stones in 1900. [Extract from Mineral Resources of the United States, Calendar Year 1900: David T. Day, Chief of Division of Mining and Mineral Resources, U. S. Geological Survey.] Washington, 1901.

—LANE, A. C. The Economic Geology of Michigan in its Relation to the Business World. [Lecture delivered at the Field Columbian Museum, Chicago, November 2, 1901.] The Michigan Miner, Saginaw, Mich., December 1, 1901.

—MERRILL, GEORGE P. On a Stony Meteorite, which fell near Felix, Perry County, Alabama, May 15, 1900. [From the Proceedings of the United States National Museum, Vol. XXIV, pp. 193–198 (with Plates XIII, XIV).] Washington, 1901.

—MOLENGRAAFF, G. A. F. Géologie de la République Sud-Africaine du Transvaal. [Extrait du Bulletin de la Société Géologique de France.] 28, Rue Serpente, VI, Paris, 1901.

—United States Department of Agriculture. Report No. 70. Exhaustion and Abandonment of Soils. Testimony of Milton Whitney, Chief of Division of Soils, before the Industrial Commission. Washington, 1901.

—United States Geological Survey. Twenty-first Annual Report, 1899–1900. Part I, Director's Report, including Triangulation, Primary Traverse, and Spirit Leveling. Part VI, Mineral Resources of the United States, 1899; Metallic Products, Coal, and Coke. Part VI (continued), Mineral Resources of the United States, 1899; Non-metallic Products, except Coal and Coke.

—Ward, Lester F. Geology of the Little Colorado Valley. [From the American Journal of Science, Vol. XII, December, 1901.]

—Warman, Philip Creveling. Catalogue and Index of the Publications of the United States Geological Survey, 1880 to 1901. [Bulletin No. 177, U. S. Geological Survey.] Washington, 1901.

—Washington Academy of Sciences, Proceedings of the.

Papers from the Harriman Alaska Expedition, XXV. The Algae. [Plates XLIII–LXII.] By De Alton Saunders. Vol. III, pp. 391–486, November 15, 1901.

Papers from the Harriman Alaska Expedition, XXVI. Harrimanella, a New Genus of Heathers. [Text Figures 62–66.] By Frederick V. Coville. Vol. III, pp. 569–576, December 6, 1901.

Papers from the Hopkins-Stanford Galapagos Expedition, 1898–9. V. Entmological Results (5): Thysanura and Termitidæ. [Text Figures 47–57.] By Nathan Banks, U. S. National Museum. Vol. III, pp. 541–546, November 29, 1901.

Papers from the Hopkins-Stanford Galapagos Expedition, 1898–9, VI. The Isopods. By Harriet Richardson, Collaborator, Smithsonian Institution. Vol. III, pp. 565–568, November 29, 1901.

Descriptions of 23 New Harvest Mice (Genus Reithrodontomys). By G. Hart Merriam. Vol. III, pp. 547–558, November 29, 1901.

Seven New Mammals from Mexico, Including a New Genus of Rodents. By G. Hart Merriam. Vol. III, pp. 559–563, November 29, 1901.

Preliminary Revision of the Pumas (Felis Concolor Group). By C. Hart Merriam. Vol. III, pp. 577–600, December 11, 1901.

—Woodworth, J. B. The History and Conditions of Mining in the Richmond Coal-Basin, Virginia. [Transactions of the American Institute of Mining Engineers (Richmond Meeting, February 1901).]

—Wright, Fred. Eugene. Die Foyaitisch-Theralthischen Eruptivegesteine der Insel Cabo Frio, Rio de Janeiro, Brasilien. [Tschermak's Mineralog. und petrographische Mittheilungen, Bd. XX, Heft 3.] Alfred Hölder, Rothenthurmstrasse 15, Wien.

INDEX TO VOLUME IX.

PAGE

Adams, Frank Dawson. Excursion to the Pyrenees in Connection with Eighth International Geological Congress - - - - - - - - - 28

Agriculture, Department of, for 1900, Year Book of the United States. Review by C. - - - - - - - - - - - - - 363

Allegany County, Maryland, The Paleozoic Formations of. Charles S. Prosser 409

Allgemeine Limnologie; Handbuch der Seenkunde. F. A. Forel. Review by R. D. S. - - - - - - - - - - - - - - - - 199

Alpen, Die vierte Eiszeit im Bereiche der. Von Albrecht Penck. Review by R. D. S. - - - - - - - - - - - - - - - - 202

American Association for the Advancement of Science, Denver Meeting. Editorial by T. C. C. - - - - - - - - - - - - 536

Ammonite-Genus from the Lower Carboniferous, Prodromites, A New. James Perrin Smith, and Stuart Weller - - - - - - - - - 255

Anthracite Coal Field, Stratigraphical succession of the Fossil Floras of the Pottsville Formation in the Southern. David White. Review by Charles R. Keyes - - - - - - - - - - - - - - 544

Arkansas, Physiography of the Boston Mountains. A. H. Purdue - - - 694

Arkansas, The Bauxite Deposits of. Charles Willard Hayes, U. S. Geological Survey. Twenty-First Annual Report. Part III. Review by Thomas L. Watson - - - - - - - - - - - - - - - 694

Arkansas Valley, Composite Genesis of, Through the Ozark Highlands. Charles R. Keyes - - - - - - - - - - - - - - - 486

Artesian Basins of Wyoming, A Preliminary Report on the. Wilbur C. Knight. Review by R. D. S. - - - - - - - - - - - - - 200

Bain, H. F., Review of Annual Report for 1900. Iowa Geological Survey - 547

Baldwin, Evelyn B. Observer Weather Bureau. Meteorological Observations of the Second Wellman Expedition. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900. Part VIII. Review by T. C. C. - - - - - - - - - 276

Basis for Geologic Mapping, The Formation as the. Edwin C. Eckel - - 708

Bauxite Deposits of Arkansas. Charles Willard Hayes, U. S. Geological Survey, Twenty-First Annual Report. Part III. Review by Thomas L. Watson - - - - - - - - - - - - - - 737

Beach Structures in the Medina Sandstone. H. L. Fairchild. Review by N. M. F. - - - - - - - - - - - - - - - - 549

Beaufort's Dyke off the Coast of the Mull of Galloway. H. G. Kinahan. Review by N. M. F. - - - - - - - - - - - - - 551

PAGE

Becraft Mountain, Columbia County, New York. The Oriskany Fauna of the. J. M. Clark. Review by S. W. - - - - - - - - - 278
Review by Charles R. Keyes - - - - - - - - - - 542
Bedford as a Formational Name, The Use of. Edgar R. Cumings - - - 232
"Bedford Limestone," On the Use of the Term. C. E. Siebenthal - - 234
Bedford Limestone, The Term. Charles S. Prosser - - - - - - 270
Biddle, H. C., The Deposition of Copper by Solutions of Ferrous Salts - - 430
Big Horn Mountains, Wyoming, Glacial Sculpture of the. François E. Matthes. Review by R. D. S. - - - - - - - - - 465
Blatchley, W. S., State Geologist, Twenty-Fifth Annual Report, Department of Geology and Natural Resources of Indiana. Review by C. E. Siebenthal - - - - - - - - - - - - - - - - 354
Border-Line between Paleozoic and Mesozoic in Western America. James Perrin Smith - - - - - - - - - - - - - - 512
Boston Mountains, Arkansas, Physiography of the. N. H. Purdue - - - 694
Branner, J. C. Editorial: Ripples of the Medina Sandstone - - - 535
Review: A Record of the Geology of Texas for the Decade Ending December 31, 1896. Frederic W. Simonds - - - - - - 91
Zinc and Lead Regions of North Arkansas, Review by C. R. Keyes - 634

Calvin, Samuel, State Geologist, Iowa Geological Survey, A. G. Leonard, Assistant State Geologist. Annual Report for 1900. Review by H. F. B. 547
Campbell, John T. Evidence of a Local Subsidence in the Interior - - 437
Canada, Summary Report of the Geological Survey Department for the year 1900. Review by C. - - - - - - - - - - - 357
Canals, Flumes, and Pipes, The Conveyance of Water in Irrigation. Samuel Fortier. Review by G. B. H. - - - - - - - - - - 361
Cave Earths, Nitrates in. Henry W. Nichols - - - - - - - - 236
Certain Peculiar Eskers and Esker Lakes of Northeastern Indiana. Charles R. Dryer - - - - - - - - - - - - - - - - 123
Charpentier, Henri. Les Minéraux utiles et leurs gisements. Géologie et Minéralogie Appliquées. Review by J. C. Branner - - - - - 198
Chamberlin, T. C. On a Possible Function of Disruptive Approach in the Formation of Meteorites, Comets, and Nebulæ - - - - - - 369
Editorials: Death of George M. Dawson - - - - - - - - 267
Death of Joseph Le Conte - - - - - - - - - - - 439
Denver Meeting of the A. A. A. S. - - - - - - - - - 536
Geologic Classification and Nomenclature - - - - - - - 633
Nomenclature in Geology - - - - - - - - - - - 267
Reviews: Annual Report of the Board of Regents of the Smithsonian Institution - - - - - - - - - - - - - - 466
Meteorological Observations of the Second Wellman Expedition by Evelyn B. Baldwin, Observer, Weather Bureau. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900, Part VII - - - - - - - - - - - 276
On Rival Theories of Cosmogony. O. Fisher - - - - - - 458

PAGE

Summary Report of the Geological Survey Department [of Canada] for the year 1900 - 357
The Geological History of the Rivers of East Yorkshire. T. R. Cowper Reed - 360
The Norwegian North Polar Expedition 1893–1896. Scientific Results. Vol. II. Edited by Fridtjof Nansen - 273
Year Book of the United States Department of Agriculture for 1900 - 363
Chemical Study in Differentiation; Part II. The Foyaite-Ijolite Series of Magnet Cove. Henry T. Washington - 645
Clark, J. M., The Oriskany Fauna of the Becraft Mountain, Columbia County, New York. Review by S. W. - 278
Classification of the Waverly Series of Central Ohio. Charles S. Prosser - 205
Coleman, A. P. Glacial and Interglacial Beds near Toronto - 285
Colorado, the Morrison Formation of Southeastern. Willis T. Lee - 343
Composite-Genesis of the Arkansas Valley through the Ozark Highlands. Charles R. Keyes - 486
Connecticut, The River System of. William Herbert Hobbs - 469
Constituents of Meteorites. I. Studies for Students. O. C. Farrington - 393
Constituents of Meteorites. II. Studies for Students. O. C. Farrington - 522
Copper, The Deposition of, by Solutions of Ferrous Salts. H. C. Biddle - 430
Correlation of the Kinderhook Formations of Southwestern Missouri. Stuart Weller - 130
Cosmogony, On the Rival Theories of. O. Fisher. Review by T. C. C. - 458
Cumings, Edgar R. The Use of Bedford as a Formational Name - 232

Darton, N. H. Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. Review by George D. Hubbard - 732
Davis, Charles A. A Second Contribution to the Natural History of Marl - 491
Dawson, George M., Death of. Editorial by T. C. C. - 267
Deposition of Copper by Solutions of Ferrous Salts. H. C. Biddle - 430
Deposits of Arkansas, The Bauxite. Charles William Hayes, U. S. Geological Survey, Twenty-first annual Reports, Part III. Review by Thomas L. Watson - 737
Derivation of the Terrestrial Spheroid from the Rhombic Dodecahedron. Charles R. Keyes - 244
Discovery of a New Fossil Tapir in Oregon. Wm. J. Sinclair - 702
Disruptive Approach in the Formation of Meteorites, Comets, and Nebulæ, On a Possible Function of. T. C. Chamberlin - 369
Dryer, Charles R. Certain Peculiar Eskers and Esker Lakes of Northeastern Indiana - 123
Lessons in Physical Geography. Review by N. M. F. - 638

Eckel, Edwin C. The Formation as the Basis for Geologic Mapping - 708
EDITORIALS:
American Association for the Advancement of Science, Denver Meeting. T. C. C. - 536

PAGE
Bates' Hole. Wilbur C. Knight. (John C. Merriam) - - - - - 70
Board of Managers of the Bureau of Geology and Mines, Missouri - 353
Classification and Nomenclature. T. C. C. - - - - - - - - 633
Cordilleran Section, Geological Society of America, Second Annual Meeting of the. John C. Merriam - - - - - - - - 68
Death of George M. Dawson. T. C. C. - - - - - - - - 267
Death of Joseph Le Conte. T. C. C. - - - - - - - - - 439
Drainage Features of California. Andrew C. Lawson. (John C. Merriam) - - - - - - - - - - - - - - - - 77
Evidences of Shallow Seas in Paleozoic Time in Southern Arizona. W. P. Blake. (John C. Merriam) - - - - - - - - 68
Excursion, Geological and Geographical, in the North Atlantic - - 191
Feldspar-Corundum Rock from Plumas County, California. Andrew C. Lawson. (John C. Merriam) - - - - - - - - - - 78
Geological Society of America, Cordilleran Section, Second Annual Annual Meeting of the. John C. Merriam - - - - - - 68
Geological Society of America, Thirteenth Meeting. J. P. I. - - 67
Geology of the Three Sisters, Oregon. H. W. Fairbanks. (John C. Merriam) - - - - - - - - - - - - - - - 73
Granites in the Klamath Mountains, On the Age of. Oscar H. Hershey. (John C. Merriam) - - - - - - - - - - - - 76
Great Basin in Eastern California and Southwestern Nevada, The Geology of the. H. W. Turner. (John C. Merriam) - - - - 73
John Day Basin, A Geological Section through the. (John C. Merriam) 71
Neocene Basins of the Klamath Mountains. F. M. Anderson. (John C. Merriam) - - - - - - - - - - - - - - - 75
Nomenclature in Geology. T. C. C - - - - - - - - - 267
Origin of the Solar System - - - - - - - - - - - - 440
Pedological Geology of California, A Sketch of. E. W. Hilgard. (John C. Merriam) - - - - - - - - - - - - - 74
Ripples of the Medina Sandstone. J. C. Branner - - - - - 535
Sierra Madre near Pasadena, The. E. W. Claypole. (John C. Merriam) - - - - - - - - - - - - - - - - 69
The Term Bedford Limestone. Charles S. Prosser - - - - - 270
Eighth International Geological Congress, Excursion to the Pyrenees in Connection with. Frank Dawson Adams - - - - - - - 28
Eiszeit im Bereiche der Alpen. Die vierte, von Albrecht Penck. Review by R. D. S. - - - - - - - - - - - - - - - - 202
Eskers and Esker Lakes of Northeastern Indiana, Certain Peculiar, Charles R. Dryer - - - - - - - - - - - - - - - 123
Evidence of a Local Subsidence in the Interior. John T. Campbell - - 437
Excursion to the Pyrenees in Connection with Eighth International Geological Congress. Frank Dawson Adams - - - - - - - - 28

Fairchild, H. L. Beach Structures in the Medina Sandstone. Review by N. M. F. - - - - - - - - - - - - - - - 549

PAGE

Farrington, O. C. The Constituents of Meteorites. I. Studies for Students 392
  - The Constituents of Meteorites. II. Studies for Students 522
  - Structure of Meteorites. I. Studies for Students 51
  - Structure of Meteorites. II. Studies for Students 174

Fenneman, N. M. Reviews: Beach Structures in the Medina Sandstone by H. L. Fairchild 549
  - Lessons in Physical Geography by Charles R. Dryer 638
  - Some Notes Regarding Vaerdal, the Great Landship, by Dr. Hans Reusch 639
  - The Beaufort's Dyke off the Coast of the Mull of Galloway, by H. G. Kinahan 551

Ferrous Salts. The Deposition of Copper, by Solutions of. H. C. Biddle 430

Fisher, O. On Rival Theories of Cosmogony. Review by T. C. C. 458

Floras of the Pottsville Formation in the Southern Anthracite Coal Field, Stratigraphical Succession of the Fossil. David White. Review by Charles R. Keyes 544

Forel, F. A. Handbuch der Seenkunde; Allgemeine Limnologie. Review by R. D. S. 199

Formation as the Basis for Geologic Mapping, The. Edwin C. Eckel 708

Fossil Tapir in Oregon, The Discovery of a New. William J. Sinclair 702

Foyaite-Ijolite Series of Magnet Cove. A Chemical Study in Differentiation. Part II. Henry S. Washington 645

Fulgurites, A Study of the Structure of. Alexis A. Julien 673

Fuller, Myron L. Probable Representatives of Pre-Wisconsin Till in Southeastern Massachusetts 311

Galloway, The Beaufort's Dyke off the Coast of the Mull of. H. G. Kinahan. Review by N. M. F. 551

Gannett, Henry. Profiles of Rivers in the United States. Review by G. B. H. 363

Geological Society of America, Thirteenth Annual Meeting. Editorial, J. P. I. 67

Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, Preliminary Description of. N. H. Darton. Review by George D. Hubbard 732

Glacial and Interglacial Beds near Toronto. A. P. Coleman 285

Glacial Work in the Western Mountains in 1901. R. D. Salisbury 718

Glaciers, The Variations of. VI. Harry Fielding Reid 250

Gould, Charles Newton. Notes on the Fossils from the Kansas-Oklahoma Red-Beds 337

Hayes, Charles Willard. The Bauxite Deposits of Arkansas. U. S. Geological Survey, Twenty-first Annual Report, Part III. Review by Thomas L. Watson 737

Heraclea, Zeiller's Flora of the Carboniferous Basin of. An illustration of Paleozoic Plant Distribution. Review by David White 192

PAGE

High Plains and Their Utilization. Willard D. Johnson. Review by George D. Hubbard - - - - - - - - - - - - - - - 734

Hobbs, William Herbert. The River System of Connecticut - - - - - 469

Hochregionen des Kaukasus, Aus den. Gottfried Merzbacher. Review by J. P. I. - - - - - - - - - - - - - - - - 359

Hubbard, George D.—Reviews: Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions of South Dakota and Wyoming. N. H. Darton 732

The High Plains and Their Utilization. Willard D. Johnson - - 734

Iddings, J. P.—Editorial: Thirteenth Meeting of the Geological Society of America - - - - - - - - - - - - - - - - 67

Review: Aus den Hochregionen des Kaukasus. Gottfried Merzbacher - 359

Indiana, Department of Geology and Natural Resources of. Twenty-fifth Annual Report. W. S. Blatchley, State Geologist. Review by C. E. Siebenthal - - - - - - - - - - - - - - - 354

Individuals of Stratigraphic Classification. Bailey Willis - - - - - 557

Interglacial Beds near Toronto, Glacial and. H. P. Coleman - - - 285

Irrigation Canals, Flumes, and Pipes, The Conveyance of Water in. Samuel Fortier. Review by G. B. H. - - - - - - - - - - - 361

Johnson, Willard D. The High Plains and Their Utilization. Review by George D. Hubbard - - - - - - - - - - - - - 734

Julien, Alexis A. A Study of the Structure of Fulgurites - - - - - 673

Kansas-Oklahoma Red-Beds, Notes on the Fossils from the. Charles Newton Gould - - - - - - - - - - - - - - - 337

Kansas, The University Geological Survey of, Vol. IV. Paleontology, Part II. Samuel W. Williston. Review by Stuart Weller - - - - - 361

Kaukasus, Aus den Hochregionen des. Gottfried Merzbacher. Review by J. P. I. - - - - - - - - - - - - - - - - 359

Keyes, Charles R. Composite Genesis of the Arkansas Valley through the Ozark Highlands - - - - - - - - - - - - - 486

Derivation of the Terrestrial Spheroid from the Rhombic Dodecahedron 244

Reviews: Three Phases of Modern Paleontology: (I) Uintacrinus: Its Structure and Relations, Frank Springer; (II) Oriskany Fauna of Becraft Mountain, John M. Clark; (III) Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field, David White - - - - - - - - - - - 539

Zinc and Lead Regions of North Arkansas. John C. Branner - - 634

Kinahan, H. G. The Beaufort's Dyke off the Coast of the Mull of Galloway. Review by N. M. F. - - - - - - - - - - - - - 551

Kinderhook Formations of Southwestern Missouri, Correlation of the. Stuart Weller - - - - - - - - - - - - - - - - 130

Knight, Wilbur C. A Preliminary Report on the Artesian Basins of Wyoming. Review by R. D. S. - - - - - - - - - - - - - 200

PAGE

Landslip, Some Notes Regarding the Great, Vaerdal. Dr. Hans Reusch. Review by N. M. F. - 639
Lead Regions of North Arkansas, and Zinc. John C. Branner. Review by C. R. Keyes - 634
Le Conte, Joseph, Death of. Editorial by T. C. C. - 439
Lee, Willis T. The Morrison Formation of Southeastern Colorado - 343
Leith, C. K. Summaries of Current North American Pre-Cambrian Literature 79-441
Leonard, A. G., Assistant State Geologist. Samuel Calvin, State Geologist; Iowa Geological Survey, Annual Report for 1900. Review by H. F. B. 547
Lime-Magnesia Rocks, Perknite. H. W. Turner - 507
Lower Carboniferous, Prodromites, a New Ammonite Genus from the. James Perrin Smith and Stuart Weller - 255

Magnet Cove, The Foyaite-Ijolite Series of; A Chemical Study in Differentiation, II. Henry S. Washington - 645
Mapping, The Formation as the Basis for Geologic. Edwin C. Eckel - 708
Marl, A Second Contribution to the Natural History of. Charles A. Davis - 491
McKinley, President, Memorial - 533
Medina Sandstone, Beach Structures in the. H. L. Fairchild. Review by N. M. F. - 549
Medina Sandstone, Ripple-marks. Editorial by J. C. Branner - 535
Memorial, President McKinley - 533
Merriam, John C. Cordilleran Section of the Geological Society of America, Second Annual Meeting - 68
Mesozoic, The Border-Line Between the Paleozoic and the, in Western America. James Perrin Smith - 512
Meteorites, Comets, and Nebulæ, On a Possible Function of Disruptive Approach in the Formation of. T. C. Chamberlin - 369
Meteorites, The Constituents of. I. Studies for Students. O. C. Farrington - 393
Meteorites, The Constituents of. II. Studies for Students. Oliver C. Farrington - 522
Minéraux utiles et leurs gisements. Géologie et minéralogie appliquées. Par Henri Charpentier. Review by J. C. Branner - 198
Miniature Overthrust Fault and Anticline, Illustrated Note on a. A. H. Purdue - 341
Monticuliporoidea, Problem of the. I. Frederick W. Sardeson - 1
Monticuliporoidea, Problem of the. II. F. W. Sardeson - 149
Morrison Formation of Southeastern Colorado, The. Willis T. Lee - 343
Mountains, Glacial Work in the Western, in 1901. R. D. Salisbury - 718

Nansen, Fridtjof, The Norwegian North Polar Expedition, 1893 to 1896. Scientific Results. Vol. I. Review by R. D. S. - 87
  Vol. II. Review by T. C. C. - 273
Natural History of Marl, A Second Contribution to the. Charles A. Davis - 491

PAGE
Nichols, Henry W., Nitrates in Cave Earths - - - - - - - - - 236
Nitrates in Cave Earths. Henry W. Nichols - - - - - - - 236
Nomenclature in Geology. Editorial by T. C. C. - - - - - - - - 267
North American Pre-Cambrian Literature, Summaries of Current. C. K. Leith - - - - - - - - - - - - - - 79, 441
Notes on the Fossils from the Kansas-Oklahoma Red-Beds. Charles Newton Gould - - - - - - - - - - - - - - - 337
Nutter, Edward Hoit, Sketch of the Geology of the Salinas Valley, California 330

Oregon, The Discovery of a New Fossil Tapir in. William J. Sinclair - - 702
Origin of the Phenocrysts in the Porphyritic Granites of Georgia. Thomas L. Watson - - - - - - - - - - - - - - 97
Origin of the Yosemite Valley, The Pleistocene Geology of the South Central Sierra Nevada with Especial Reference to the. Henry Ward Turner. Review by R. D. S. - - - - - - - - - - - - 90
Overthrust Fault and Anticline, Illustrated Note on a Miniature. A. H. Purdue - - - - - - - - - - - - - - - 341
Ozark Highlands, Composite-Genesis of the Arkansas Valley Through the. Charles R. Keyes - - - - - - - - - - - - - 486

Paleontology, Part II. Samuel W. Williston. The University Geological Survey of Kansas, Vol. IV. Review by Stuart Weller - - - - 361
Paleontology, Three Phases of Modern.—Review by Charles R. Keyes - - 539
Paleozoic and Mesozoic, The Border Line between, in Western America. James Perrin Smith - - - - - - - - - - - - 512
Paleozoic Formations of Allegany County, Maryland. Charles S. Prosser - 409
Paleozoic Plant Distribution, An Illustration of, Zeiller's Flora of the Carboniferous Basin of Heraclea. Review by David White - - - - - 192
Penck, Albrecht, Die vierte-Eiszeit im Bereiche der Alpen. Review by R. D. S. - - - - - - - - - - - - - - - 202
Perknite (Lime-Magnesia Rocks). H. W. Turner - - - - - - - - 507
Petroleum, Texas. William Battle Phillips. Review by C. E. S. - - - 637
Phases of Modern Paleontology, Three. Review by Charles R. Keyes - - 539
Phenocrysts in the Porphyritic Granites of Georgia, On the Origin of the. Thomas L. Watson - - - - - - - - - - - - 97
Phillips, William Battle. Texas Petroleum. Review by C. E. S. - - - 637
Physical Geography, Lessons in. Charles R. Dryer. Review by N. M. F. - 638
Physiography of the Boston Mountains, Arkansas. A. H. Purdue - - - 694
Plains and Their Utilization, The High. Willard D. Johnson. Review by George D. Hubbard - - - - - - - - - - - - 734
Polar Expedition, The Norwegian North, 1893–1896, Scientific Results. Edited by Fridtjof Nansen:
    Vol. I. Review by R. D. S. - - - - - - - - - - 87
    Vol. II. Review by T. C. C. - - - - - - - - - - 273
Possible Function of Disruptive Approach in the Formation of Meteorites, Comets and Nebulæ, On a. T. C. Chamberlin - - - - - - 369

PAGE

Pottsville Formation in the Southern Anthracite Coal Field, Stratigraphical Succession of the Fossil Floras of the. David White. Review by Charles R. Keyes - - - 544
Pre-Cambrian Literature, Summaries of Current North American. C. K. Leith - - - 79, 441
Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. N. H. Darton. Review by George D. Hubbard - - 732
Pre-Wisconsin Till in Southeastern Massachusetts, Probable Representatives of. Myron L. Fuller - - - 311
Probable Representatives of Pre-Wisconsin Till in Southeastern Massachusetts. Myron L. Fuller - - - 311
Problem of the Monticuliporoidea. I. Frederick W. Sardeson - - - 1
Problem of the Monticuliporoidea. II. F. W. Sardeson - - - 149
Prodromites, A New Ammonite-Genus from the Lower Carboniferous. James Perrin Smith and Stuart Weller - - - 255
Prosser, Charles S. The Classification of the Waverly Series of Central Ohio 205
    The Paleozoic Formations of Allegany County, Maryland - - - 409
Purdue, A. H., Illustrated Note on a Miniature Overthrust Fault and Anticline 341
    Physiography of the Boston Mountains - - - 694
    Valleys of Solution in Northern Arkansas - - - 47
Pyrenees, Excursion to the, in connection with Eighth International Geological Congress. Frank Dawson Adams - - - 28

RECENT PUBLICATIONS - - - 92, 203, 280, 364, 467, 552, 642, 740
Red-Beds, Notes on the Fossils from the Kansas-Oklahoma. Charles Newton Gould - - - 337
Reed, F. R. Cowper, The Geological History of the Rivers of East Yorkshire. Review by T. C. C. - - - 360
Reid, Harry Fielding, The Variations of Glaciers, VI - - - 250
Reusch, Dr. Hans, Some Notes Regarding Vaerdal, The Great Landslip. Review by N. M. F. - - - 639
REVIEWS: Annual Report of the Board of Regents of the Smithsonian Institution. (C.) - - - 466
    A Preliminary Report on the Artesian Basins of Wyoming. Wilbur C. Knight. (R. D. S.) - - - 200
    Aus den Hochregionen des Kaukasus. Gottfried Merzbacher. (J. P. I.) 359
    Beach Structures in the Medina Sandstone. H. L. Fairchild. (N. M. F.) - - - 549
    Conveyance of Water in Irrigation Canals, Flumes, and Pipes. Samuel Fortier. (G. B. H.) - - - 361
    Department of Geology and Natural Resources of Indiana. Twenty-Fifth Annual Report. W. S. Blatchley, State Geologist. (C. E. Siebenthal) - - - 354
    Die vierte Eiszeit im Bereiche der Alpen. Von Albrecht Penck. (R. D. S.) - - - 202

Geological History of the Rivers of East Yorkshir
Reed. (T. C. C.) - - - - - - -
Geological Map of West Virginia. I. C. White. -
Géologie et Minéralogie appliquées. Les minéraux
gisements. Par Henri Charpentier. (J. C. Branner
Glacial Sculpture of the Big Horn Mountains, Wy
Matthes. (R. D. S.) - - - - - -
Handbuch der Seenkunde; Allgemeine Limnologie
(R. D. S) - - - - - - - - -
Iowa Geological Survey. Samuel Calvin, State G
Leonard, Assistant State Geologist. Annual R
(H. F. B.) - - - - - - - -
Lessons in Physical Geography. Charles R. Dryer. (
Meteorological Observations of the Second Wellman
Evelyn B. Baldwin, Observer Weather Bureau. Re
of the Weather Bureau, United States Departmen
1899–1900, Part VII. (T. C. C.) - - -
Oriskany Fauna of the Becraft Mountain, Columbia Co
J. M. Clark. (S. W.) - - - - - -
(Charles R. Keyes) - - -
Preliminary Description of the Geology and Water
Southern Half of the Black Hills and Adjoining
Dakota and Wyoming. N. H. Darton. Extract fr
first Annual Report of the United States Geologic
1900, Part IV. (George D. Hubbard) - -
Profiles of Rivers in the United States, Henry Gannett.
Record of the Geology of Texas for the Decade endi
1896. Frederic W. Simonds. (J. C. Branner) -
Rival Theories of Cosmogony. O. Fisher. (T. C. C.)
Some Notes Regarding Vaerdal; The Great Land
Reusch. (N. M. F.) - - - - - -
Summaries of Current North American Pre-Cambrian
Leith - - - - - - - - -
Summary Report of the Geological Survey Departmen
the Year 1900. (C.) - - - - - -
Texas Petroleum. William Battle Phillips. (C. E. S.)
The Bauxite Deposits of Arkansas. Charles Willard
first Annual Report, United States Geological S
(Thomas L. Watson) - - - - - -
The Beauforts' Dyke, off the Coast of the Mull of
Kinahan. (N. M. F.) - - - - - -
The High Plains and Their Utilization. Willard D. J
from the Twenty-first Annual Report of the United
Survey, 1899–1900. Part IV. Hydrography. (Geo
The Norwegian North Polar Expedition, 1893–1896:
Vol. II. Edited by Fridtjof Nansen. (T. C. C.)

PAGE

  The Norwegian Polar Expedition, 1893–1806: Scientific Results. Edited by Fridtjof Nansen. Vol. I. (R. D. S.) - - - - - 87
  The Pleistocene Geology of the South Central Sierra Nevada, with Especial Reference to the Origin of the Yosemite Valley. Henry Ward Turner. (R. D. S.) - - - - - - - - - - 90
  Three Phases of Modern Paleontology: (I) Uintacrinus; Its Structure and Relations. Frank Springer. (II) Oriskany Fauna of Becraft Mountain. John M. Clark. (III) Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field. David White. (Charles R. Keyes) - - - - - 539
  University Geological Survey of Kansas, Vol. IV. Paleontology, Part II. Samuel W. Williston, (S. W.) - - - - - - - 362
  Year Book of the United States Department of Agriculture for 1900. (C.) - - - - - - - - - - - - - - - 363
  Zeiller's Flora of the Carboniferous Basin of Heraclea: An Illustration of Paleozoic Plant Distribution. (David White) - - - - - 192
  Zinc and Lead Regions of North Arkansas. John C. Branner. (C. R. Keyes) - - - - - - - - - - - - - - - 634

Rhombic Dodecahedron, Derivation of the Terrestrial Spheriod from the. Charles R. Keyes - - - - - - - - - - - - - 244
Rivers in the United States, Profile of. Henry Gannett. Review by G. B. H. 363
Rivers of East Yorkshire, The Geological History of the. F. R. Cowper Reed. Review by T. C. C. - - - - - - - - - - - - - 360
River System of Connecticut, The. William Herbert Hobbs - - - - 469

Salinas Valley, California, Sketch of the Geology of. Edward Hoit Nutter - 330
Salisbury, R. D. Glacial Work in the Western Mountains in 1901 - - 718
  Reviews: Die vierte-Eiszert im Bereiche der Alpen. Von Albrecht Penck - - - - - - - - - - - - - - - 202
  Glacial Sculpture of the Big Horn Mountains, Wyoming. François E. Matthes - - - - - - - - - - - - - - - 465
  Handbuch der Seenkunde: Allgemeine Limnologie. F. A. Forel - 199
  Norwegian Polar Expedition, 1893 to 1896, Scientific Results. Edited by Fridtjof Nansen. Vol. I - - - - - - - - - - 87
  Report on the Artesian Basins of Wyoming, A Preliminary. Wilbur C. Knight - - - - - - - - - - - - - - - 200
  The Pleistocene Geology of the South Central Sierra Nevada, with Especial Reference to the Origin of the Yosemite Valley. Henry Ward Turner - - - - - - - - - - - - - 90
Sardeson, Frederick W. Problem of the Monticuliporoidea - - - - 1
Scientific Results. The Norwegian North Polar Expedition, 1893 to 1896.
  Vol. I. Edited by Fridtjof Nansen. Review by R. D. S. - - - 87
  Vol. II. Review by T. C. C. - - - - - - - - - - 273
Sculpture of the Big Horn Mountains, Wyoming, Glacial. François E. Matthes. Review by R. D. S. - - - - - - - - 465
Siebenthal, C. E., On the Use of the Term "Bedford Limestone" - - 234

PAGE

Geological History of the Rivers of East Yorkshire. F. R. Cowper Reed. (T. C. C.) 360

Geological Map of West Virginia. I. C. White. 640

Géologie et Minéralogie appliquées. Les minéraux utiles et leurs gisements. Par Henri Charpentier. (J. C. Branner) 198

Glacial Sculpture of the Big Horn Mountains, Wyoming. François Matthes. (R. D. S.) 465

Handbuch der Seenkunde; Allgemeine Limnologie. F. A. Forel. (R. D. S) 199

Iowa Geological Survey. Samuel Calvin, State Geologist; A. G. Leonard, Assistant State Geologist. Annual Report for 1900. (H. F. B.) 547

Lessons in Physical Geography. Charles R. Dryer. (N. M. F.) 638

Meteorological Observations of the Second Wellmann Expedition, by Evelyn B. Baldwin, Observer Weather Bureau. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900, Part VII. (T. C. C.) 276

Oriskany Fauna of the Becraft Mountain, Columbia County, New York. J. M. Clark. (S. W.) 278
(Charles R. Keyes) 542

Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. N. H. Darton. Extract from the Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part IV. (George D. Hubbard) 732

Profiles of Rivers in the United States, Henry Gannett. (G. B. H.) 363

Record of the Geology of Texas for the Decade ending December 31, 1896. Frederic W. Simonds. (J. C. Branner) 91

Rival Theories of Cosmogony. O. Fisher. (T. C. C.) 458

Some Notes Regarding Vaerdal; The Great Landslip. Dr. Hans Reusch. (N. M. F.) 639

Summaries of Current North American Pre-Cambrian Literature. C. K. Leith 79, 441

Summary Report of the Geological Survey Department [of Canada] for the Year 1900. (C.) 357

Texas Petroleum. William Battle Phillips. (C. E. S.) 637

The Bauxite Deposits of Arkansas. Charles Willard Hayes. Twenty-first Annual Report, United States Geological Survey, Part III. (Thomas L. Watson) 737

The Beauforts' Dyke, off the Coast of the Mull of Galloway. H. G. Kinahan. (N. M. F.) 551

The High Plains and Their Utilization. Willard D. Johnson. Extract from the Twenty-first Annual Report of the United States Geological Survey, 1899–1900. Part IV. Hydrography. (George D. Hubbard) 734

The Norwegian North Polar Expedition, 1893–1896: Scientific Results. Vol. II. Edited by Fridtjof Nansen. (T. C. C.) 273

PAGE
The Norwegian Polar Expedition, 1893–1806: Scientific Results. Edited by Fridtjof Nansen. Vol. I. (R. D. S.) 87
The Pleistocene Geology of the South Central Sierra Nevada, with Especial Reference to the Origin of the Yosemite Valley. Henry Ward Turner. (R. D. S.) 90
Three Phases of Modern Paleontology: (I) Uintacrinus; Its Structure and Relations. Frank Springer. (II) Oriskany Fauna of Becraft Mountain. John M. Clark. (III) Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field. David White. (Charles R. Keyes) 539
University Geological Survey of Kansas, Vol. IV. Paleontology, Part II. Samuel W. Williston, (S. W.) 362
Year Book of the United States Department of Agriculture for 1900. (C.) 363
Zeiller's Flora of the Carboniferous Basin of Heraclea: An Illustration of Paleozoic Plant Distribution. (David White) 192
Zinc and Lead Regions of North Arkansas. John C. Branner. (C. R. Keyes) 634
Rhombic Dodecahedron, Derivation of the Terrestrial Spheriod from the. Charles R. Keyes 244
Rivers in the United States, Profile of. Henry Gannett. Review by G. B. H. 363
Rivers of East Yorkshire, The Geological History of the. F. R. Cowper Reed. Review by T. C. C. 360
River System of Connecticut, The. William Herbert Hobbs 469

Salinas Valley, California, Sketch of the Geology of. Edward Hoit Nutter 330
Salisbury, R. D. Glacial Work in the Western Mountains in 1901 718
Reviews: Die vierte-Eiszert im Bereiche der Alpen. Von Albrecht Penck 202
Glacial Sculpture of the Big Horn Mountains, Wyoming. François E. Matthes 465
Handbuch der Seenkunde: Allgemeine Limnologie. F. A. Forel 199
Norwegian Polar Expedition, 1893 to 1896, Scientific Results. Edited by Fridtjof Nansen. Vol. I 87
Report on the Artesian Basins of Wyoming, A Preliminary. Wilbur C. Knight 200
The Pleistocene Geology of the South Central Sierra Nevada, with Especial Reference to the Origin of the Yosemite Valley. Henry Ward Turner 90
Sardeson, Frederick W. Problem of the Monticuliporoidea 1
Scientific Results. The Norwegian North Polar Expedition, 1893 to 1896.
Vol. I. Edited by Fridtjof Nansen. Review by R. D. S. 87
Vol. II. Review by T. C. C. 273
Sculpture of the Big Horn Mountains, Wyoming, Glacial. François E. Matthes. Review by R. D. S. 465
Siebenthal, C. E., On the Use of the Term "Bedford Limestone" 234

PAGE

Reviews: Texas Petroleum, by William Battle Phillips - - - - - 637
Twenty-fifth Annual Report, Department of Geology and Natural Resources of Indiana. W. S. Blatchley, State Geologist - - - 354
Simonds, Frederic W., A Record of the Geology of Texas for the Decade Ending December 31, 1896. Review by J. C. Branner - - - - - 91
Sinclair, Wm. J. The Discovery of a New Fossil Tapir in Oregon - - 702
Sketch of the Geology of the Salinas Valley, California. Edward Hoit Nutter 330
Smith, James Perrin, and Stuart Weller. Prodromites, A New Ammonite-Genus from the Lower Carboniferous - - - - - - - 255
Smith, James Perrin. The Border-Line Between the Paleozoic and the Mesozoic in Western America - - - - - - - - - - 512
Smithsonian Institution, Annual Report of the Board of Regents of the. Review by C. - - - - - - - - . - - - - - 466
Solar System, Origin of. Editorial - - - - - - - - - - 440
Solution, Valleys of, in Northern Arkansas. A. H. Purdue - - - - - 47
Springer, Frank. Uintacrinus; Its Structure and Relations. Review by Charles R. Keyes - - - - - - - - - - - - 539
Stratigraphic Classification, Individuals of. Bailey Willis - - - - - 557
Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field. David White. Review by Charles R. Keyes - - - - - - - - - - - - 544
Structure of Fulgurites, A Study of the. Alexis A. Julien - - - - - 673
Structure of Meteorites. I. Studies for Students. O. C. Farrington - - 51
Structure of Meteorites. II. Studies for Students. O. C. Farrington - - 174
STUDIES FOR STUDENTS: The Constituents of Meteorites. I. O. C. Farrington - - - - - - - - - - - - - - - 393
The Constituents of Meteorites. II. Oliver C. Farrington - - - 522
The Structure of Meteorites. I. O. C. Farrington - - - - - 51
The Structure of Meteorites. II. O. C. Farrington - - - - - 174
Study of the Structure of Fulgurites. Alexis A. Julien - - - - - - 673
Subsidence in the Interior, Evidence of a Local. John T. Campbell - - 437

Tapir, in Oregon, the Discovery of a New Fossil. William J. Sinclair - - 702
Terrestrial Spheroid from the Rhombic Dodecahedron, Derivation of. Charles R. Keyes - - - - - - - - - - - - - - - 244
Texas Petroleum. William Battle Phillips. (C. E. S.) - - - - - - 637
Texas, Record of the Geology of, for the Decade Ending December 31, 1896. Frederick W. Simonds. (J. C. Branner) - - - - - - - 91
Turner, H. W. Perknite (Lime-Magnesia Rocks) - - - - - - - 507

Uintacrinus: Its Structure and Relations. Frank Springer. Review by Charles R. Keyes - - - - - - - - - - - - 539

Vaerdal; Some Notes Regarding the Great Landslip. Dr. Hans Reusch. Review by N. M. F. - - - - - - - - - - - - 639

PAGE
Valleys of Solution in Northern Arkansas. A. H. Purdue - - - - - 47
Variations of Glaciers. VI. Harry Fielding Reid - - - - - - - 250

Washington, Henry S. The Foyaite-Ijolite Series of Magnet Cove. A Chemical Study in Differentiation - - - - - - - - - - 645
Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, Preliminary Description of the Geology and. N. H. Darton. Review by George D. Hubbard 732
Watson, Thomas L. On the Origin of the Phenocrysts in the Porphyritic Granites of Georgia- - - - - - - - - - - 97
Review of the Bauxite Deposits of Arkansas, by Charles Willard Hayes, United States Geological Survey, Twenty-first Annual Report, Part III - - - - - - - - - - - - - - - - - 737
Waverly Series of Central Ohio, Classification of. Charles S. Prosser - - 205
Weller, Stuart, and James Perrin Smith; Prodromites, A New Ammontie Genus from the Lower Carboniferous - - - - - - - - - - 255
Weller, Stuart, Correlation of the Kinderhook Formations of Southwestern Missouri - - - - - - - - - - - - - - - - 130
Reviews: The Oriskany Fauna of the Becraft Mountain, Columbia County, New York, by J. M. Clark - - - - - - - - - - 278
The University Geological Survey of Kansas, Vol. IV. Paleontology, Part II. Samuel W. Williston - - - - - - - - - - 362
Wellman Expedition, Meteorological Observations of the Second, by Evelyn B. Baldwin, Observer Weather Bureau. Report of the Chief of the Weather Bureau, United States Department of Agriculture, 1899–1900, Part VII. Review by T. C. C. - - - - - - - 276
West Virginia, Geological Map of, I. C. White - - - - - - - 640
White, David. Review of Zeiller's Plant Flora of the Carboniferous Basin of Heraclea. An Illustration of Paleozoic Plant Distribution - - 192
Stratigraphical Succession of the Fossil Floras of the Pottsville Formations in Southern Anthracite Coal Field. Review by Charles R. Keyes - - - - - - - - - - - - - - - - 544
White, I. C., Geological Map of West Virginia - - - - - - - 640
Willis, Bailey, Individuals of Stratigraphic Classification - - - - - 557

Yorkshire, the Geological History of the Rivers of East, F. R. Cowper Reed. Review by T. C. C. - - - - - - - - - - - - - 360

Zinc and Lead Regions of North Arkansas, John C. Branner. Review by C.

Farrington, Oliver C. The Pre-Terrestrial History of Meteorites - - - 623
Foyaite-Ijolite Series of Magnet Cove. A Chemical Study in Differentiation. Henry S. Washington - - - - - - - - - - - 607
Igneous Rocks of the Great Basin, Variations of Texture in Certain Tertiary. J. E. Spurr - - - - - - - - - - - - - 586
Meteorites, The Pre-Terrestrial History of. Oliver C. Farrington - - - 623
Spurr, J. E. Variations of Texture in Certain Tertiary Igneous Rocks of the Great Basin - - - - - - - - - - - - - 586
Tertiary Igneous Rocks of the Great Basin, Variations in Texture. J. E. Spurr 586
Texture, Variations of, in Certain Tertiary Igneous Rocks of the Great Basin. J. E. Spurr - - - - - - - - - - - 586
Time-Values in Geology, The Discrimination of. Henry Shaler Williams - 570
Washington, Henry S. The Foyaite-Ijolite Series of Magnet Cove - - 607

Volume IX Number 8

THE
Journal of Geology

A Semi-Quarterly Magazine of Geology and Related Sciences

NOVEMBER-DECEMBER, 1901

EDITORS

T. C. CHAMBERLIN, *in General Charge*

R. D. SALISBURY
Geographic Geology
J. P. IDDINGS
Petrology
STUART WELLER
Paleontologic Geology
R. A. F. PENROSE, JR.
Economic Geology
C. R. VAN HISE
Structural Geology
W. H. HOLMES
Anthropic Geology

ASSOCIATE EDITORS

SIR ARCHIBALD GEIKIE
Great Britain
H. ROSENBUSCH
Germany
CHARLES BARROIS
France
ALBRECHT PENCK
Austria
HANS REUSCH
Norway
GERARD DE GEER
Sweden
G. K. GILBERT
Washington, D. C.
H. S. WILLIAMS
Yale University
C. D. WALCOTT
U. S. Geological Survey
J. C. BRANNER
Stanford University
I. C. RUSSELL
University of Michigan
W. B. CLARK,
Johns Hopkins University
O. A. DERBY
Brazil

CHICAGO
The University of Chicago Press
LONDON: LUZAC & CO. 46 GREAT RUSSELL ST., W. C.

$3.00 A YEAR 50 CENTS A COPY

Copyright 1901 by The University of Chicago

THE

Dr. Deimel Underwear

INSURES FREEDOM FROM COLDS

Don't you believe it?

Look about your friends and note those who are constantly troubled with colds, la grippe, rheumatism, and allied affections. You'll find the majority of them are wearers of woolen undergarments. You never heard of an habitual wearer of the

Dr. Deimel Underwear

being troubled with colds, rheumatism, or afraid of drafts.

A trial at once will insure health and comfort.

This Trade Mark on every garment.

FREE BOOKLET and samples of the cloth sent by addressing

The Deimel Linen-Mesh System Co.,

491 Broadway, New York.

San Francisco, Cal., - 111 Montgomery St.
Washington, D. C., - 728 15th St., N. W.
Montreal, Can., - - 2202 St. Catherine St.
London, E. C., Eng., - - 10-12 Bread St.

Enlarged Section through a

KREMENTZ ONE PIECE COLLAR BUTTON

Strongest where strain is greatest.

Cannot break: If damaged from any cause you get another without charge.

Easy to button and unbutton. When buttoned it stays buttoned.

Made of One Piece of Metal without Seam or Joint.

Ask the Dealer for the "KREMENTZ."

The genuine have the name stamped on the back. The quality is guaranteed.

Our Booklet, THE STORY OF A COLLAR BUTTON, free for the asking, tells all about Krementz Buttons, and illustrates the different styles.

KREMENTZ & CO.,
34 Chestnut St., Newark, N. J.

SET MAKES AN ELEGANT AND LASTING CHRISTMAS GIFT

23 YEARS

the Standard of Excellence

Jaeger Woolens

Only True Sanitary Underwear

ALL WEIGHTS FOR ALL WANTS

ILLUSTRATED CATALOGUE FREE

NEW YORK: 16 West 23d Street; 155 157 Broadway
BROOKLYN: 504 Fulton Street
BOSTON: 230-232 Boylston Street
PHILADELPHIA: 924 Chestnut Street
CHICAGO: 82 State Street

Agents in all Principal Cities

"RIDE A COCK-HORSE TO BANBURY CROSS.
TO SEE A FINE LADY UPON A WHITE HORSE.
RINGS ON HER FINGERS, AND BELLS ON HER TOES.
SHE SHALL HAVE MUSIC WHEREVER SHE GOES."

SO SINGS THE FOND MOTHER IN NURSERY RHYME
TO HER GLAD INFANT, THE WHILE KEEPING. TIME;
AND SO CAN ALL MOTHERS WITH TUNEFUL REFRAIN
DELIGHT IN THEIR INFANTS, WHOSE HEALTH THEY MAINTAIN.
THROUGH
MRS. WINSLOW'S SOOTHING SYRUP
OVER FIFTY YEARS SOLD
TO MILLIONS OF MOTHERS IN THE NEW WORLD AND OLD.

LIEBIG
COMPANY'S
EXTRACT OF BEEF

"Tis the little things that tell."

REFUSE COUNTERFEITS

J. v. Liebig

LOOK FOR THIS SIGNATURE IN BLUE

Huyler's

Pure! Delicious!!

BONBONS AND CHOCOLATES.
LARGE ASSORTMENT OF
FANCY BOXES AND BASKETS etc.
CANDIES SENT EVERYWHERE BY MAIL & EXPRESS

Orders by mail carefully executed.
Huyler's
863 BROADWAY. bet. 17th. & 18th Sts. New York.

From Bean to Cup
Huyler's
COCOA AND CHOCOLATE
PURE! HEALTHFUL!!

SOLD AT OUR STORES AND BY GROCERS EVERYWHERE.

The Improved
BOSTON GARTER
The Standard for Gentlemen
ALWAYS EASY

The Name "BOSTON GARTER" is stamped on every loop.

The Velvet Grip
CUSHION BUTTON CLASP

Lies flat to the leg—never Slips, Tears nor Unfastens.

SOLD EVERYWHERE.

Sample pair, Silk 50c, Cotton 25c
Mailed on receipt of price.

GEO. FROST CO., Makers,
Boston, Mass., U.S.A.

EVERY PAIR WARRANTED

WINTER
CRUISES
TO THE
West Indies
THE
Spanish Main
AND TO
Mexico.

BY THE **HAMBURG-AMERICAN LINE**

Two Grand Winter Cruises

TO THE

WEST INDIES

By the Specially Constructed, Magnificent, New, Twin-Screw Cruising Yacht

PRINZESSIN VICTORIA LUISE

OF THE

HAMBURG-AMERICAN LINE

LEAVING NEW YORK Jan. 4th, 1902; Feb. 8th, 1902

These cruises offer unparalleled opportunities to visit—under the most favorable auspices, and upon a specially designed and perfectly equipped steamship—the new possessions of the U. S. in the WEST INDIES, the neighboring islands, the SPANISH MAIN, and MEXICO.

ITINERARY

FIRST CRUISE from New York to San Juan (Porto Rico); **St. Thomas; St. Pierre** (Martinique); **Port of Spain and La Brea** (Trinidad); **La Guayra; Puerto Cabello** (Venezuela); **Curacao; Kingston** (Jamaica); **Santiago and Havana** (Cuba); **Charleston, S. C., and return to New York. A total distance of 5,320 miles, occupying 30 days. WITH SIDE TRIPS to CARACAS and VALENCIA, VENEZUELA.**

SECOND CRUISE from New York to San Juan (Porto Rico); **Domingo City** (Santo Domingo); **Kingston** (Jamaica); **Santiago de Cuba; Vera Cruz** (Mexico); **Havana** (Cuba); **Charleston, S. C., and return to New York. A total distance of 5,510 miles, occupying 28 days. WITH SIDE TRIP TO MEXICO CITY.**

For further information, rates, etc., apply to Dept. 17 of the

HAMBURG-AMERICAN LINE

35-37 Broadway, New York
1229 Walnut St., Philadelphia
159 Randolph St., Chicago
70 State St., Boston
106 N. Broadway, St. Louis
401 California St., San Francisco

Our Engraving

Of Wedding Stationery has something to commend itself to people of taste and refinement over the common, ordinary kind.

Our Prices

Are as low as work of our standard can be named.

We send you finely engraved plate and 100 of latest style visiting cards for $1.50.

Monogram and initial work a specialty.

High class correspondence papers.

S. D. Childs & Co.
140-142 Monroe St.
Established 1837 CHICAGO.

BARGAINS IN VIOLINS

An opportunity to get a fine instrument very low. Students violins (dated 1700—1830) from $50 up. Concert instruments by the old masters, in fine preservation, from $150 up. Note these few examples: Testore 1750, $150; Grancino, $200; Pressenda, $200; Gabrielli, $200; Kloz, $125; Old Strad copy, $100, and many others. Four magnificent Stradivarius, Guarnerius and Amati very low. Send for our beautiful catalog of old violins (Free). Contains historical sketches of the old masters of Cremona and Brescia from 1540; illustrated; with fac-simile labels, also a descriptive list of old violins possessing the pure mellow tone, and costing from $25.00 to $5,000.00. A formal Certificate of Genuineness accompanies each violin. Monthly payments accepted.

A SPECIAL OFFER. We will send several old violins on approval and allow ten days examination.

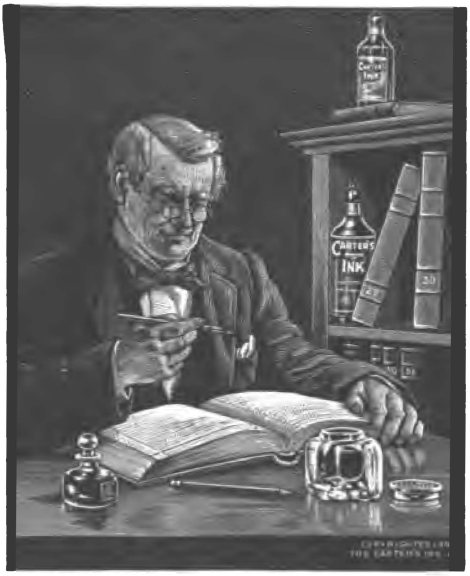
LYON & HEALY, 31 Adams St., Chicago.

PIANO Do You Want a Genuine Bargain in a Piano?

We have hundreds of Upright Pianos returned from renting by persons moving which must be disposed of at once as we cannot make room for them in our salesrooms. These pianos include Steinways, Knabes, Fischers, Sterlings and other well known makes. Many of them cannot be distinguished from new, yet all are offered at a great discount from prices when new. Uprights as low as $100. Very easy terms of payment to reliable persons. Freight would cost you about $5. New large size mahogany pianos, with mandolin attachment, $175, sent anywhere on easy payments. Write at once for complete list and full particulars. You can make a great saving by securing your piano from us. Every piano warranted exactly as represented. **LYON & HEALY, 91 Adams St., Chicago.**

The World's Largest Music House.

"AFTER ALL" **CARTER'S INK** "IS THE BEST"



An Old Bookkeeper is Discriminating
Better take his advice and use CARTER'S
Send for booklet "Inklings"—Free
THE CARTER'S INK CO. - BOSTON, MASS.

A.P.W. BRAND

For Only **$1.00**

We will deliver anywhere in the U. S. we can reach by express [we will pay express charges] a case containing enough

TOILET PAPER

To last any average family a full year; finest satin tissue, A. P. W. BRAND.

If you ever saw better at anything like the price per 1000 sheets, we will refund the dollar. Our guarantee is good—we are the largest makers in the world, and originated the perforated roll.

Sample Sheets and Booklet mailed FREE

A. P. W.
Paper Company
Montgomery St., Albany, N.Y.

A.P.W. BRAND

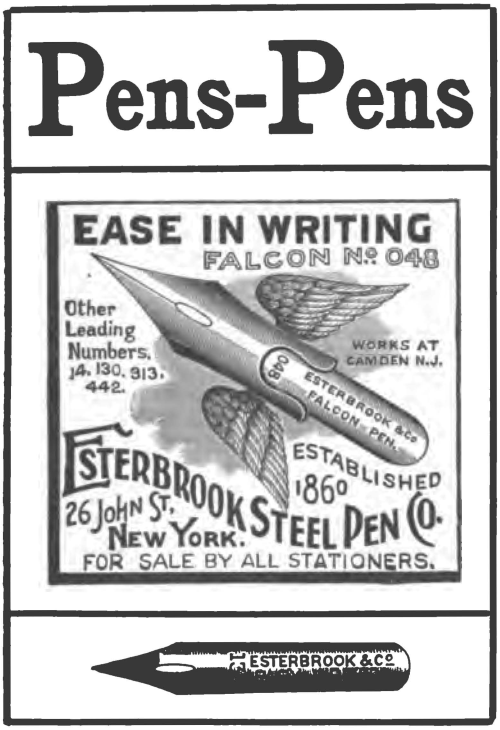
PAGE

Reviews: Texas Petroleum, by William Battle Phillips - - - - 637
  Twenty-fifth Annual Report, Department of Geology and Natural Resources of Indiana. W. S. Blatchley, State Geologist - - - 354
Simonds, Frederic W., A Record of the Geology of Texas for the Decade Ending December 31, 1896. Review by J. C. Branner - - - - - 91
Sinclair, Wm. J. The Discovery of a New Fossil Tapir in Oregon - - 702
Sketch of the Geology of the Salinas Valley, California. Edward Hoit Nutter 330
Smith, James Perrin, and Stuart Weller. Prodromites, A New Ammonite-Genus from the Lower Carboniferous - - - - - - - 255
Smith, James Perrin. The Border-Line Between the Paleozoic and the Mesozoic in Western America - - - - - - - - - - 512
Smithsonian Institution, Annual Report of the Board of Regents of the. Review by C. - - - - - - - - . - - - - - 466
Solar System, Origin of. Editorial - - - - - - - - - - 440
Solution, Valleys of, in Northern Arkansas. A. H. Purdue - - - - 47
Springer, Frank. Uintacrinus; Its Structure and Relations. Review by Charles R. Keyes - - - - - - - - - - - - - 539
Stratigraphic Classification, Individuals of. Bailey Willis - - - - 557
Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field. David White. Review by Charles R. Keyes - - - - - - - - - - - - - 544
Structure of Fulgurites, A Study of the. Alexis A. Julien - - - - 673
Structure of Meteorites. I. Studies for Students. O. C. Farrington - - 51
Structure of Meteorites. II. Studies for Students. O. C. Farrington - - 174
STUDIES FOR STUDENTS: The Constituents of Meteorites. I. O. C. Farrington - - - - - - - - - - - - - - - - 393
  The Constituents of Meteorites. II. Oliver C. Farrington - - - 522
  The Structure of Meteorites. I. O. C. Farrington - - - - - 51
  The Structure of Meteorites. II. O. C. Farrington - - - - - 174
Study of the Structure of Fulgurites. Alexis A. Julien - - - - - 673
Subsidence in the Interior, Evidence of a Local. John T. Campbell - - 437

Tapir, in Oregon, the Discovery of a New Fossil. William J. Sinclair - - 702
Terrestrial Spheroid from the Rhombic Dodecahedron, Derivation of. Charles R. Keyes - - - - - - - - - - - - - - - 244
Texas Petroleum. William Battle Phillips. (C. E. S.) - - - - - - 637
Texas, Record of the Geology of, for the Decade Ending December 31, 1896. Frederick W. Simonds. (J. C. Branner) - - - - - - - 91
Turner, H. W. Perknite (Lime-Magnesia Rocks) - - - - - - - 507

Uintacrinus: Its Structure and Relations. Frank Springer. Review by Charles R. Keyes - - - - - - - - - - - - 539

Vaerdal; Some Notes Regarding the Great Landslip. Dr. Hans Reusch. Review by N. M. F. - - - - - - - - - - - - 639



Pens-Pens

EASE IN WRITING
FALCON Nº 048
Other Leading Numbers. 14. 130. 313. 442.
WORKS AT CAMDEN N.J.
048 ESTERBROOK & Co FALCON PEN.
ESTABLISHED 1860
ESTERBROOK STEEL PEN CO.
26 JOHN ST. NEW YORK.
FOR SALE BY ALL STATIONERS.

ESTERBROOK & Cº

The Remington Typewriter

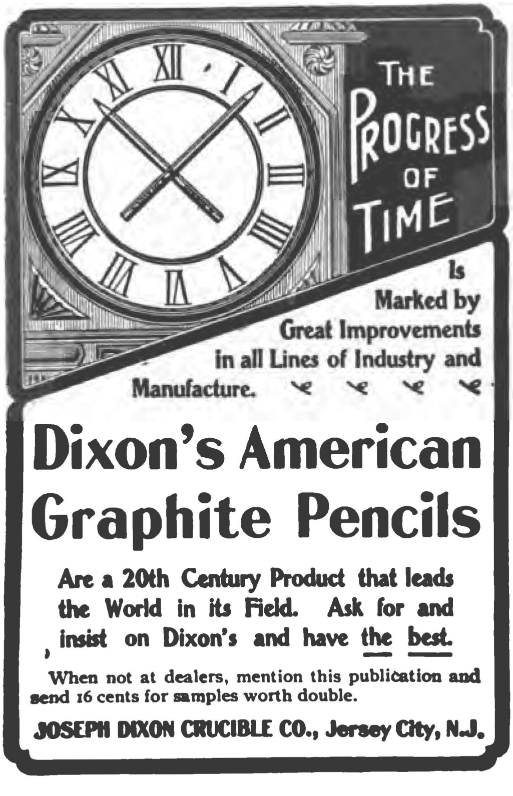
has the

Remington

Lightest Touch

that saves labor; and does the quickest work—that saves time. Time and labor saved by the REMINGTON

Wyckoff, Seamans & Benedict, New York.



THE PROGRESS OF TIME Is Marked by Great Improvements in all Lines of Industry and Manufacture.

Dixon's American Graphite Pencils

Are a 20th Century Product that leads the World in its Field. Ask for and insist on Dixon's and have the best.

When not at dealers, mention this publication and send 16 cents for samples worth double.

JOSEPH DIXON CRUCIBLE CO., Jersey City, N.J.

IT'S A WONDER

For Bankers, Lawyers, Doctors, Clergymen, and all busy people

All Scrap Books 9½ x 11¼ Inches

An excellent Christmas Gift

FOUNTAIN PEN
POST
LINCOLN
ARMY AND NAVY
The Americ
LININGS
FRAZE
THE FAMILY
TRIMMING
ORIGINAL
STANDARD
SLEIGH
EVER CO

Don't Lay Clippings and Other Papers on your desk. You'll lose them. Tuck them in the pockets of a **Perfect Scrap Book** and keep them ready for reference. Indispensable to all intellectual people. For **One Dollar** we will send you a 24-page (72 pockets) **Perfect Scrap Book** in substantial half linen binding. Library edition 204 pockets, half Morocco, $3.00; College edition, 120 pockets, half Morocco, $2.00. A trial size portfolio (fine for private correspondence) 12 pockets for 20c. all postpaid on receipt of price.

Circular free on request. Leading Stationers.

THE PERFECT SCRAP BOOK CO.
Dept. V. **150 Nassau St., New York City**

We've a Wallet size handy for the pocket. Sent postpaid for 25 cents

INSURE IN

The TRAVELERS,

of Hartford, Conn.

Oldest,
Largest,
and Best

Life, . . .
Endowment,
and Accident
. . . Insurance

OF ALL FORMS.

Health Policies.

Indemnity for Disability caused by Sickness.

Liability Insurance.

Manufacturers and Mechanics, Contractors, and Owners of Buildings, Horses, and Vehicles, can all be protected by policies in THE TRAVELERS INSURANCE COMPANY.

Paid-up Cash Capital, . .	$1,000,000.00
ASSETS, ...	30,861,030.06
Liabilities, ...	26,317,903.25
EXCESS, 3½ per cent basis,	4,543,126.81

Life Insurance in force, . . .	$109,019,851.00
Returned to Policy holders, .	42,643,384.92

J. G. BATTERSON, President.
S. C. DUNHAM, Vice President.
H. J. MESSENGER, Actuary.
JOHN E. MORRIS, Secretary.
E. V. PRESTON, Sup't of Agencies

Dining Cars
Service à la Carte

ROSES are always on the tables, and delicate china, glass and silver add to the pleasure of a dinner well cooked and daintily served

All the Season's Delicacies
at Very Moderate Prices

Burlington Route

OUR 8,000 miles of railroad reach out from Chicago, Peoria and St. Louis to all the important cities in the west and northwest such as

ST. PAUL
MINNEAPOLIS
OMAHA
KANSAS CITY
DENVER

If you are going to any of these places or to the Pacific coast, kindly let me send you time tables and other information about our train service.

P. S. EUSTIS,
Gen'l Pass. Agt., C. B. & Q. R. R.,
CHICAGO, ILL.

Comfort in Travel

will be found in high degree on the fast trains of the MICHIGAN CENTRAL.

New York and Boston Special
Leaves CHICAGO 10.30 a. m.
Arrives NEW YORK 1.30 p. m., BOSTON 3.00 p. m.

Fast Eastern Express
Leaves CHICAGO 3.00 p. m.
Arrives NEW YORK 6.00 p. m., BOSTON 9.00 p. m.

New York State Special
Leaves CHICAGO 5.30 p. m.
Arrives NEW YORK 8.45 p. m., BOSTON 11.30 p. m.

Atlantic Express
Leaves CHICAGO 11.30 p. m.
Arrives NEW YORK 7.00 a. m., BOSTON 8.46 a. m.

Detroit Night Express
Leaves CHICAGO 9.35 p. m.
Arrives DETROIT 7.15 a. m.

Through Pullman Sleeping Cars
The Dining Car service
is noted for its excellence.

City Ticket Office, 119 Adams Street, Chicago.

R. H. L'HOMMEDIEU,
General Superintendent.

O. W. RUGGLES,
General Passenger and Ticket Agent.

[illegible]

A DOCTOR'S REASON

"Doctor, why do you ask nurses to use Ivory Soap?"

"Two or three years ago [illegible]"

Ivory Soap — 99 44/100 Per Cent. Pure.

Field of Ordinary Binocular. Field of STEREO Binocular.

Bausch & Lomb-Zeiss STEREO Binoculars

Are used by the armies and navies of the great nations, by up-to-date tourists, sportsmen, yachtsmen, ranchmen, because they are the most perfect optically and mechanically, have immense field of view, power, and give, as no other glass does, a STEREOSCOPIC image.

Bausch & Lomb Prism Binoculars

Stand next in excellence. Cost less.
Descriptive booklet mailed on request.
SOLD BY ALL DEALERS.

Bausch & Lomb Optical Co.
New York ROCHESTER, N. Y. Chicago

Bausch & Lomb Plastigmat f-6.8

The Perfect Photo Lens, as the above picture made with it shows, is fast enough for the fastest work, and in addition, has the proper length of focus for the best pictorial results, the highest optical corrections and either combination may be used separately for long distance or portrait photography. Booklet with five difficult pictures mailed free. Buy your camera with it. Buy it for your camera.

Bausch & Lomb Optical Co.
New York ROCHESTER, N. Y. Chicago

JUST OUT

A PLATE ATTACHMENT

For No. 3 Folding Pocket Kodak

HAVE ONE FITTED TO YOURS

Enables the owner to use either plates or films and to focus picture on the ground glass

PRACTICAL REASONABLE

We also fit our celebrated **Double Anastigmat Lens** to these cameras

No. 3 FOLDING POCKET KODAK, with **GOERZ DOUBLE-ANASTIGMAT**, New Automatic TIB Shutter and Plate Attachment, with six holders, complete, **$62.80**, net cash.

Plate Attachment and Six Holders, **$7.65**, net.

Write for further information to your dealer or to

C. P. Goerz Optical Works
52 EAST UNION SQUARE, NEW YORK

COPYRIGHT 1900 BY THE PROCTER & GAMBLE CO. CINCINNATI

A DOCTOR'S REASON.

"Doctor, why do you tell nurse to use Ivory Soap?"

"Two or three years ago, the students at a college in which I am interested, bought some of each kind of soap for sale in the city and made analyses of them. The result was that purity, price and uniformity of quality, indicated Ivory as the soap to be recommended. Since then I direct my patients to use it exclusively."

Ivory Soap — $99^{44}/_{100}$ Per Cent. Pure.

The Journal of Geology

Is issued Semi-Quarterly on or about the following dates: February 1, March 15, May 1, June 15, August 1, September 15, November 1, December 15.

CONTENTS

THE FOYAITE-IJOLITE SERIES OF MAGNET COVE. A CHEMICAL STUDY IN DIFFERENTIATION. Part II. HENRY S. WASHINGTON 645

PECULIAR EFFECTS DUE TO A LIGHTNING DISCHARGE ON LAKE CHAMPLAIN IN AUGUST, 1900. WILLIAM HALLOCK 671

A STUDY OF THE STRUCTURE OF FULGURITES - - - - - - - - - - - ALEXIS A. JULIEN 673

PHYSIOGRAPHY OF THE BOSTON MOUNTAINS, ARKANSAS - - - - - - - A. H. PURDUE 694

THE DISCOVERY OF A NEW FOSSIL TAPIR IN OREGON - - - - - - - WILLIAM J. SINCLAIR 702

THE FORMATION AS THE BASIS FOR GEOLOGIC MAPPING - - - - - - EDWIN C. ECKEL 708

GLACIAL WORK IN THE WESTERN MOUNTAINS IN 1901. - - - - - - ROLLIN D. SALISBURY 718

REVIEWS: *Preliminary Description of the Geology and Water Resources of the Southern half of the Black Hills and Adjoining Regions in South Dakota and Wyoming*, N. H. DARTON (GEORGE D. HUBBARD), 732; *The High Plains and Their Utilization*, WILLARD D. JOHNSON (GEORGE D. HUBBARD), 734; *The Bauxite Deposits of Arkansas*, CHARLES WILLARD HAYES (THOMAS L. WATSON), 737.

RECENT PUBLICATIONS - 740

INDEX TO VOLUME IX. - 743

Separates, if desired, must be ordered in advance of publication. Separates of leading articles will be printed as ordered, of which 50 (without covers) will be furnished *gratis*, the actual cost of the remainder (and covers, if desired) to be paid for by the author. The table below shows the *approximate* cost of separates consisting of plain text or text with line-engravings. The actual cost may vary from the figures given, and will depend upon the amount of work in re-making the pages into forms, press work, paper, binding, etc. Separates containing half-tones may be expected to cost somewhat more than the rates given, the increase depending upon the number of cuts and the amount of work required upon them.

Number of copies	50	100	150	200
Letter-press, for 4 pages or less	$1.60	$2.00	$2.25	$2.50
Letter-press, for 8 pages or less	2.25	2.75	3.15	3.50
Letter-press, for 16 pages or less	4.00	5.00	5.80	6.50
Single plates (1 double = 2 single)	1.00	1.35	1.70	2.00
Covers, with title (paper like JOURNAL cover)	1.50	2.00	2.50	3.00

Manuscripts.—Contributors are requested to write scientific and proper names with particular care and in citations to follow the form shown in the pages of the JOURNAL. Manuscripts should be sent to **Editor of The Journal of Geology, The University of Chicago, Chicago, Ill.**

Books and Pamphlets for Review should be sent to the same address.

Missing Numbers will be replaced *free* only when claim is made within thirty days after receipt of the number following.

All remittances should be made payable to the order of The University of Chicago.

All correspondence regarding subscriptions, advertisements, and bills rendered, should be addressed to The University of Chicago Press, Chicago, Ill.

[Entered at the Post-Office at Chicago, Ill., as second-class mail matter.]

FAC ET SPERA

Every Geologist

SHOULD BE FAMILIAR WITH
THE PROMINENT WORKS OF

Gebrüder Borntraeger

PUBLISHERS

Geologisches Centralblatt—Geological Review—Revue géologique—Anzeiger für Geologie, Petrographie, Palæontologie und verwandte Wissenschaften. In Verbindung mit zahlreichen Mitarbeitern herausgegeben von PROFESSOR DR. K. KEILHACK, Landesgeologen in Berlin.

Published bi-monthly. Subscription price, $8.00 a year.

Devoted to the interests of geology and the allied sciences. Gives an accurate account of all books and papers and maps, etc., that appear on geology. Reviews in German, English, and French languages.

Sample copies free on request. Address:

Gebrüder Borntraeger

PUBLISHERS

Schönebergerstrasse 17a BERLIN, S. W. 46

Standard Gift Books

Balzac's Complete Dramatic Works

Five delightful dramas and comedies, teeming with intense human interest. Written at the height of Balzac's brilliant career. Most exquisite examples of his inimitable character creations.

First and only English version

No set complete without the plays

Balzac's dramatic writings are the most fascinating of his masterpieces; they grasp and retain the reader's rapt attention, they depict, in vivid and charming style, the motives and emotions of the human heart; they are bright, crisp, witty

Conversational Novels

Now ready. Two 12mo vols., illustrated. English cloth, deckle edges, gold tops, in a box, ... **$2.50**

Frolics of the A B C.

The most delightful and instructive children's book published. Teaches the alphabet unconsciously and pleasingly. The quaint antics of the "lettersprites" are clever, original and amusing. Just the book for little tots. Printed in ten colors. Boards, cloth back, ... **75c**

Baby Goose; His Adventures.

By Fannie E. Ostrander, illustrated by Hirchert. Fairly bubbling over with clean, wholesome fun for the children. Every page superbly illustrated. Book and cover printed in twelve colors. Bound in boards, fancy wrapper, ... **$1.25**

The Heart of a Boy.

Holiday Edition de Luxe. From the 224th edition of Edmondo de Amicis. 83 full-page half-tones and 26 text etchings. Printed on fine half-tone paper.

8vo, silk cloth, gilt top, illustrated, . **$1.25**

School edition, supplementary reading, . . . **75c**

Fireside Battles.

By Annie G. Brown. A story for girls. Tells the brave, cheery way to face hard problems Illustrated by J. C. Leyendecker. *Holiday Edition de Luxe.* 8vo, cloth, illuminated cover, ... **$1.25**

Cloth edition, illustrated, ... **75c**

The Famous Adventures of the Brownies.

150 illustrations by Palmer Cox. A book of delightful animal stories for children, by the well known writer of fairy tales, E. Veale. Also contains nine full-page drawings by Mr. Cox, illustrating the famous nursery rhyme, 'Who Killed Cock Robin?" Cloth, 12mo, handsome inlaid cover panel in four colors, ... **75c**

The Life Work of WILLIAM McKINLEY

The aim has been to make this work reliable and authentic, an honor to our beloved President, and worthy of a place in every library. A shining example in manhood and patriotism. Special features invaluable for historical reference. Superbly illustrated; tastily bound; large, clear type; superfine paper. Over 800 pages. *Agents wanted everywhere.* Sample copy postpaid on receipt of price. Special library edition, $1.25

Cloth, inlaid cover panel, ... **75c**

World's Best Proverbs

and Short Quotations. By Geo. H. Opdyke, M.A. Arranged alphabetically by subjects. Library edition. Full leather, full gilt, 8 engravings, ... **$1.50**

Cloth edition, illustrated, ... **$1.00**

The New Century Standard Letter-Writer.

By Alfred B. Chambers. Models of correct society forms, invitations, acceptances, condolences; sensible and bright love-letters; how to address the President, Members of the Cabinet and high officials.

Cloth, special design, ... **75c**

Board covers, special design, ... **50c**

Opie Read's Novels

The flower of American fiction. New 12mo edition of Mr. Read's best stories, at popular prices; printed on high-grade stock, with cover design in two colors. The best value ever offered in the copyrighted works of a popular novelist. Ten different titles. Send for list. Sold singly or in sets. Per volume, ... **75c**

Standard Juveniles.

Five splendid books for boys and girls from seven to seventy Two Chums, Air Castle Don, Tan Pile Jim, Dick and Jack's Adventures, and Rex Wayland's Fortune. Good, wholesome stories; elevating in tone. 12mo. Uniform cloth binding. Per volume, ... **75c**

El Centiloquio de Santillana.

The poem of the ages. Written in 1444 for the guidance of the Spanish crown prince. Every student of Spanish should possess this exquisite work. Full Spanish text, with English glossary. Also eighty Spanish proverbs with English translations. Red Line Souvenir Edition. Cloth, with inlaid cover panel, . . . **$1.00**

Modern Webster Dictionary.

Printed from new type. 60,000 words, with those recently coined, and definitions. 432 pp. Illustrated. Largely used in schools. Recommended by College Presidents and Superintendents. Stiff cloth, red edges, ... **25c**

Stiff silk cloth, indexed, ... **50c**

Flexible leather, full gilt, indexed, ... **$1.00**

Also Dictionaries in Foreign Languages.

For Sale by Leading Booksellers, or mailed direct. Illustrated Catalogue free.

LAIRD & LEE, Publishers, CHICAGO, U.S.A.

"A Weekly Feast to Nourish Hungry Minds."—*N. Y. Evangelist.*

FOUNDED BY E. LITTELL IN 1844

THE LIVING AGE

THE LIVING AGE presents the cream of foreign periodical literature, and reprints without abridgment the most noteworthy essays, *travel sketches*, *fiction*, *social and political papers*, and discussions of *literary*, *artistic*, and *scientific* subjects from the leading quarterlies, monthly magazines and reviews, and literary and scientific weekly journals.

THE LIVING AGE holds a unique position in the periodical world as a weekly eclectic magazine. Intelligent Americans who want presented to them from week to week the most important and timely articles from foreign periodicals find what they want in THE LIVING AGE, *and can find it nowhere else.*

Special Announcement to New Subscribers for 1902

FREE! To all New Subscribers to **THE LIVING AGE** for the year 1902 there will be sent **FREE**, until the edition is exhausted, the **SEVENTEEN WEEKLY ISSUES** for the four months September, October, November, and December, 1901.

☞ SEND AT ONCE AND SECURE ADVANTAGE OF THIS SPLENDID OFFER

P. O. Box 5206 THE LIVING AGE COMPANY, BOSTON

SUBSCRIPTION PRICE, SIX DOLLARS A YEAR. **SINGLE NUMBER, FIFTEEN CENTS**

THE LIVING AGE COMPANY, P. O. Box 5206, 13½ Bromfield St., Boston

---

ONE CENT A WEE

PUBLIC OPINION

For Ten Weeks' Subscription

PUBLIC OPINION is now an indispensable 32-page weekly magazine, comprising in its 52 issues a grand total of over 1700 pages of reading matter, and over 1000 illustrations, including reproductions of the cleverest current cartoons. Its readers, independent of other periodicals, are fully abreast of the times, sufficiently well posted to discuss with intelligence all sides of every question of the hour, whether political, social, religious, educational, scientific, financial, literary, or artistic.

PUBLIC OPINION'S field is as wide as the range of human interests. It is read by more representative people than any other weekly magazine. In addition to its own editors, its staff comprises the editors of the 3000 dailies, weeklies, and monthlies required to produce one weekly issue of PUBLIC OPINION.

THIS SPECIAL INTRODUCTORY OFFER gives you ten numbe about 350 pages (regular price, $1.00), for the price of one issue (ten cents)—the c of postage. Send at once your name, address, and ten cents (coin or stamps) to

PUBLIC OPINION, 16 UNIVERSITY PLACE, NEW YORK CIT

BOOKSELLERS
STATIONERS

A. C. McCLURG
& COMPANY

Standard
Miscellaneous
Illustrated and
Fine Bound
Gift Books
Wedding and
Reception
Invitations and
Visiting Cards
Engraved

A.C. McCLURG & CO.
215-221 Wabash Av., CHICAGO

PUBLISHERS
IMPORTERS

WEBSTER'S INTERNATIONAL

WEBSTER'S INTERNATIONAL DICTIONARY

A Dictionary of English, Biography, Geography,

NEW EDITION. 25,00

Prepared under the direct supervision of W. T. HARRIS, Ph.D.,
Commissioner of Education, assisted by a large corps of co

New Plates Throughout. Rich Bindings. 2364 Pages. 50

Useful
Reliable
An Ideal Christmas Prese

Also Webster's Collegiate Dictionary with a valuable Sco
"First class in quality, second class in size." *Nicholas Mu*

Specimen pages, etc., of both books sent on applicatio

G. & C. MERRIAM CO., Publishers, Springfield, M

When calling please ask to see Mr. Grant

BOOKS AT

LIBERAL DISCOUNT

BEFORE BUYING BOOKS,
WRITE FOR QUOTATIONS

An assortment of catalogues and special slips of Books at reduced prices sent for 10-cent stamp. . . . . .

To the Reader:—

Please remember that whenever you need a BOOK or any information about BOOKS, if you will address me, I will try to please you by attention and low prices.

Write me of your wants, or call and inspect stock, and in either case I will make you SPECIAL PRICES.

F. E. GRANT,
23 W. 42d Street,
NEW YORK

Mention this Advertisement and receive a Discount.

THE PR
OF TH
COI

By WILLIA

RECAST fro
ered befo
cational A
ton, South Car
The substance
given as a cours
University of Cl

12mo, paper, 25c (
of price b

The Universit
CHICAG

A complete Catal
request.

R. R. Donnelley & S

The Lakeside Press

PRINTERS AND BINDERS

THE PRINTING OF BOOKS DEMANDING TASTE AND CAREFUL
TION, PRIVATE EDITIONS, COLLEGE CATALOGUES AND ANN
SPECIALTY. WE PRINT MORE FINE BOOKS THAN ALL OTHER
WEST OF NEW YORK. OUR NEW FACTORY, RUN ENTIRELY B
TRICITY, IS THE MOST ADVANCED PRINTING PLANT IN THE C
THE LAKESIDE PRESS BLDG., PLYMOUTH PLACE, COR. POLK, C

Blennerhassett

BLENNERHASSETT
A ROMANCE
THE DUEL BETWEEN AARON BURR AND ALEXANDER HAMILTON
C. H. CLARK PUBLISHING CO. BOSTON

A Thrilling Romance

OF AN INTENSELY DRAMATIC FLAVOR

"Nearly every chapter is full of incident and action and there are dramatic touches which display fine literary skill. The author's canvas is crowded with interesting personages of importance.

"Mr. Pidgin has greatly increased our respect for Burr, and has set us thinking.

"If the historical novel is to remain a fixed institution, we shall be happy to see it take the form of works similar to Blennerhassett."—*Richmond Dispatch, September 15, 1901.*

12 Full-page Illustrations. *Price $1.50*

By CHARLES FELTON PIDGIN, author of

Quincy Adams Sawyer

"The best New England story ever written."

Now Nearing its Two-hundredth Thousand

AT ALL BOOKSELLERS,

In preparation MISS PETTICOATS

If you have not read "Home Thoughts" you have missed the literary treat of the year. A notable critic compares its style to that of Washington Irving and George Wm. Curtis. It isn't a continuous story, you can read a chapter at a time. Exceedingly interesting in every line, it touches deeply that which is nearest and dearest to us all. The relations of husband and wife, parent and child, and the broad field of home life give the chief themes. No recent book is so valuable as a help to right thinking and right living as "Home Thoughts."

FOURTH EDITION IN PRESS. **CLOTH, $1.50**

THE BEST GIFT BOOK IS

Home Thoughts

By "C"

Dr. A. H. Bradford says: "One of the sanest, soundest, and most helpful books of the kind that I ever read."

Sold by All Booksellers Sent, Postpaid, by

A. S. BARNES & CO., 156 Fifth Av., New York

OUR CATALOGUE FREE TO ANY ADDRESS

"The Prudential Girl of 1902"

This A
Cal

for 1902
printed i
size 10
combines
beauty;
wall de
home or
free. F
mail cou

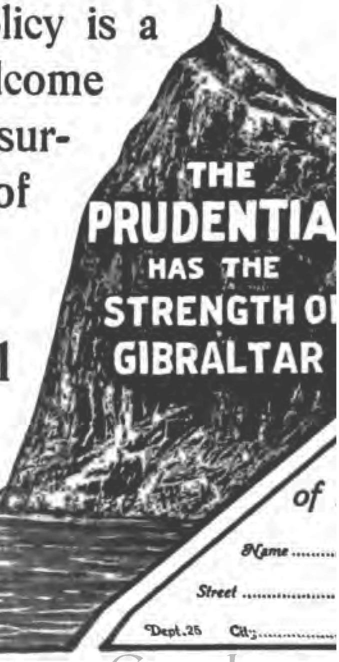
The Pruden

Life Insurance Policy is a generous and welcome Christmas gift, assuring your family of future comfort.

Write for information Dept. 25

The Prudential
Insurance Co. of America

JOHN F. DRYDEN, President.
HOME OFFICE: Newark, N. J.



of

Name ....
Street ....
Dept. 25 City..........

BUFFALO LITHIA WATER IN URIC ACID DIATHESIS, GOUT, RHEUMATISM, ETC.: THIS WATER DISSOLVES URIC ACID AND PHOSPHATIC SEDIMENTS, ETC., ETC.

John V. Shoemaker, M. D., LL. D., *Professor of Materia Medica and Therapeutics in the Medico-Chirurgical College of Philadelphia, etc., in the New York Medical Journal, June. 22, 1899:*

"The **BUFFALO LITHIA WATER** is doubly efficient in **Rheumatism and Gout. It dissolves Uric Acid and Posphatic sediments,** as well as other products difficult of elimination, while at the same time it exerts a moderately stimulant effect upon the renal cells, and thereby facilitates the swift removal of insoluable materials from the body. Without such action insoluable substances will precipitate in the Kidneys and Bladder. The intense suffering produced by **Stone,** together with consecutive **pyelitis and cystitis,** are avoided by prompt elimination. Unquestionably, although the speedy removal of **Uric Acid** and other products of faulty tissue change is of conspicuous benefit, **yet to PREVENT** their formation is a service still more important. **This service is performed by the BUFFALO LITHIA WATER** when it corrects those **digestive failures** which are responsible for the production of deleterious materials."

The late Hunter McGuire, M.D., LL. D., *Formerly President and Professor of Clinical Surgery, University College of Medicine, Richmond, Va., and Ex-President of the American Medical Association, says:*

"**BUFFALO LITHIA WATER** as an **alkaline diuretic is invaluable. In Uric Acid Gravel,** and indeed in **diseases generally dependent upon a Uric Acid Diathesis, it is a remedy of extraordinary potency.** I have prescribed it in cases of **Rheumatic Gout** which had resisted the ordinary remedies, with wonderfully good results. **I have used it also in my own case, being a great sufferer from this malady, and have derived more benefit from it than from any other remedy."**

Dr. P. B. Barringer, *Professor of Physiology and Surgery, University of Virginia:*

"In more than twenty years of practice I have used **Lithia** as an anti-uric acid agent many times, and have tried it in a great variety of forms, both in the **NATURAL WATERS and in TABLETS.** As the result of this experience, I have no hesitation in stating that for **prompt results I have found nothing to compare with BUFFALO LITHIA WATER in preventing uric acid deposits in the body.** My experience with it as a solvent of old existing deposits (calculi) has been relatively limited, and I hesitate to compare it here with other forms to their disadvantage; but for the first class of conditions above set forth I feel that **BUFFALO LITHIA WATER STANDS ALONE."**

Dr. Thomas H. Buckler, *of* **Paris** *(Formerly of Baltimore),* ***Suggestor of Lithia** as a **Solvent** for **Uric Acid,** says:*

"Nothing I could say would add to the well-known reputation of the **BUFFALO LITHIA WATER.** I have frequently used it with good results in **URIC ACID DIATHESIS, RHEUMATISM,** and **GOUT,** and with this object I have ordered it to Europe. **Lithia is in no form so valuable as where it exists in the carbonate, the form in which it is found in BUFFALO LITHIA WATER,** nature's mode of solution and division in water which has passed through Lepidolite and Spondumne Mineral formations."

Dr. J. W. Mallet, *Professor of Chemistry, University of Virginia.* Extract from report of analysis of **Calculi** discharged by patients under the action of **BUFFALO LITHIA WATER** Spring No. 2.

"It seems on the whole probable that the action of the water is **PRIMARILY and MAINLY EXERTED upon URIC ACID AND THE URATES,** but when these constituents occur along with and as **cementing matter to Phosphatic or Oxalic Calculus materials, the latter** may be so detached and broken down as to disintegrate the **Calculus** as a whole in these cases, also thus admitting of Urethral discharge."

James L. Cabell, M. D., A.M., LL. D., *Formerly Professor of Physiology and Surgery in the Medical Department of the University of Virginia, and President of the National Board of Health, says:*

"**BUFFALO LITHIA WATER in Uric Acid Diathesis is a well-known therapeutic resource. It should be recognized by the profession as an article of Materia Medica."**

BUFFALO LITHIA WATER is for sale by Grocers and Druggists generally.

TESTIMONIALS WHICH DEFY ALL IMPUTATION OR QUESTIONS SENT TO ANY ADDRESS

PROPRIETOR. BUFFALO LITHIA SPRINGS. VIRGINIA

LOOK AT THE LABELS!
THE GENUINE
BAKER'S
COCOA
AND
CHOCOLATE
PUT UP IN PACKAGES LIKE THESE

MOST AND BEST FOR THE MONEY
WALTER BAKER & CO., LTD.
ESTABLISHED 1780. DORCHESTER, MASS.

WE
PIA

All that Ar
skill devise
of a piano,
WEBER

Case desig
artistic an
simple and

Mahogany, Sa
Flemish Oak,

Special ca
are correct
the Louis
Renaissan

WEBER WA
Fifth Avenue,
266 Wab

SAPOL

Whenever you hear your bright tea-kettle
To his mate, in a voice soft and low;
You will find that ere long, she will join
To the praise of SAPOLIO.